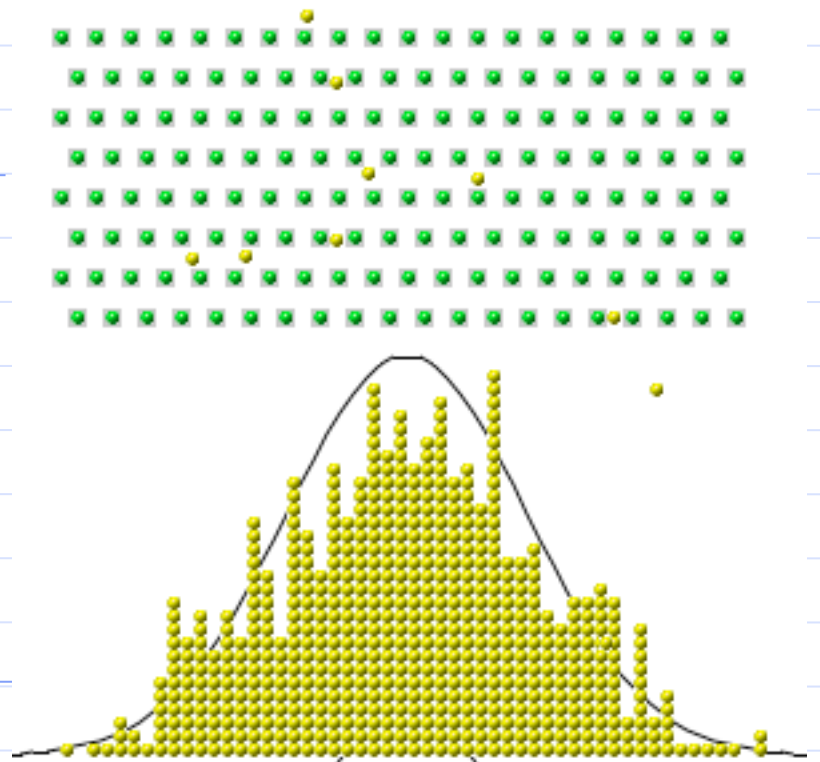


Action-Oriented Energy Benchmarking

Evan Mills, Ph.D.
Lawrence Berkeley
National Laboratory
EMills@lbl.gov



ACG 6th ANnual Conference on Total Building Commissioning
Las Vegas, April 16, 2010

Origins: Sea-level observation ("bench" is old word for shore)

Tasmanian coastal
Benchmark c.1841

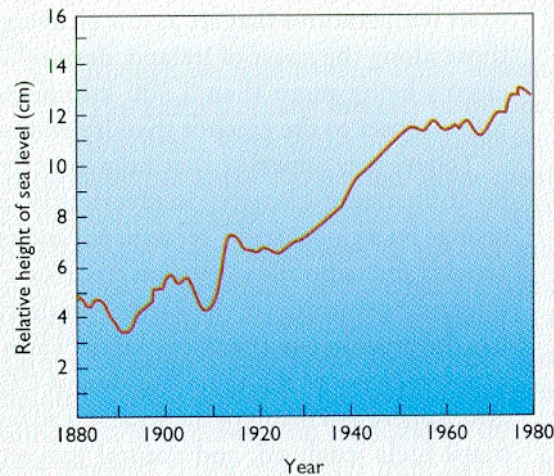
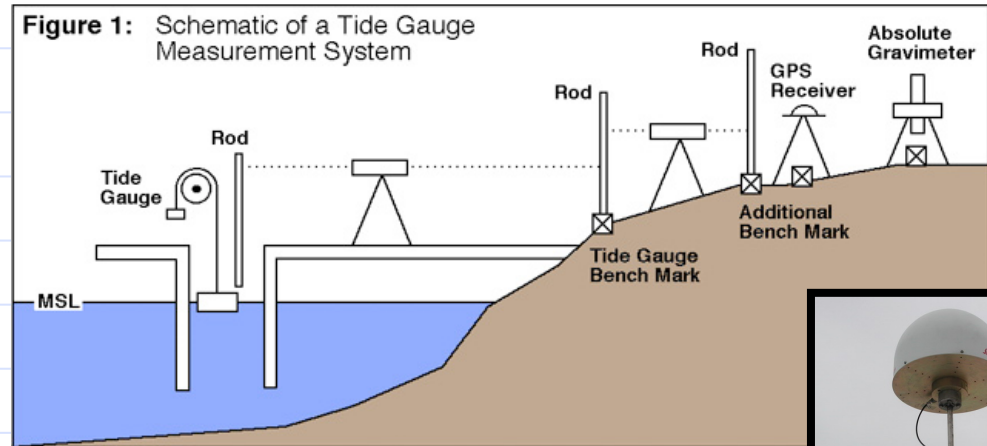
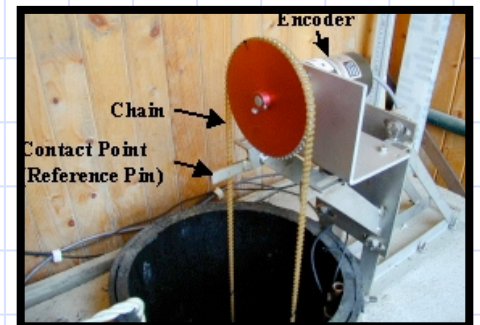
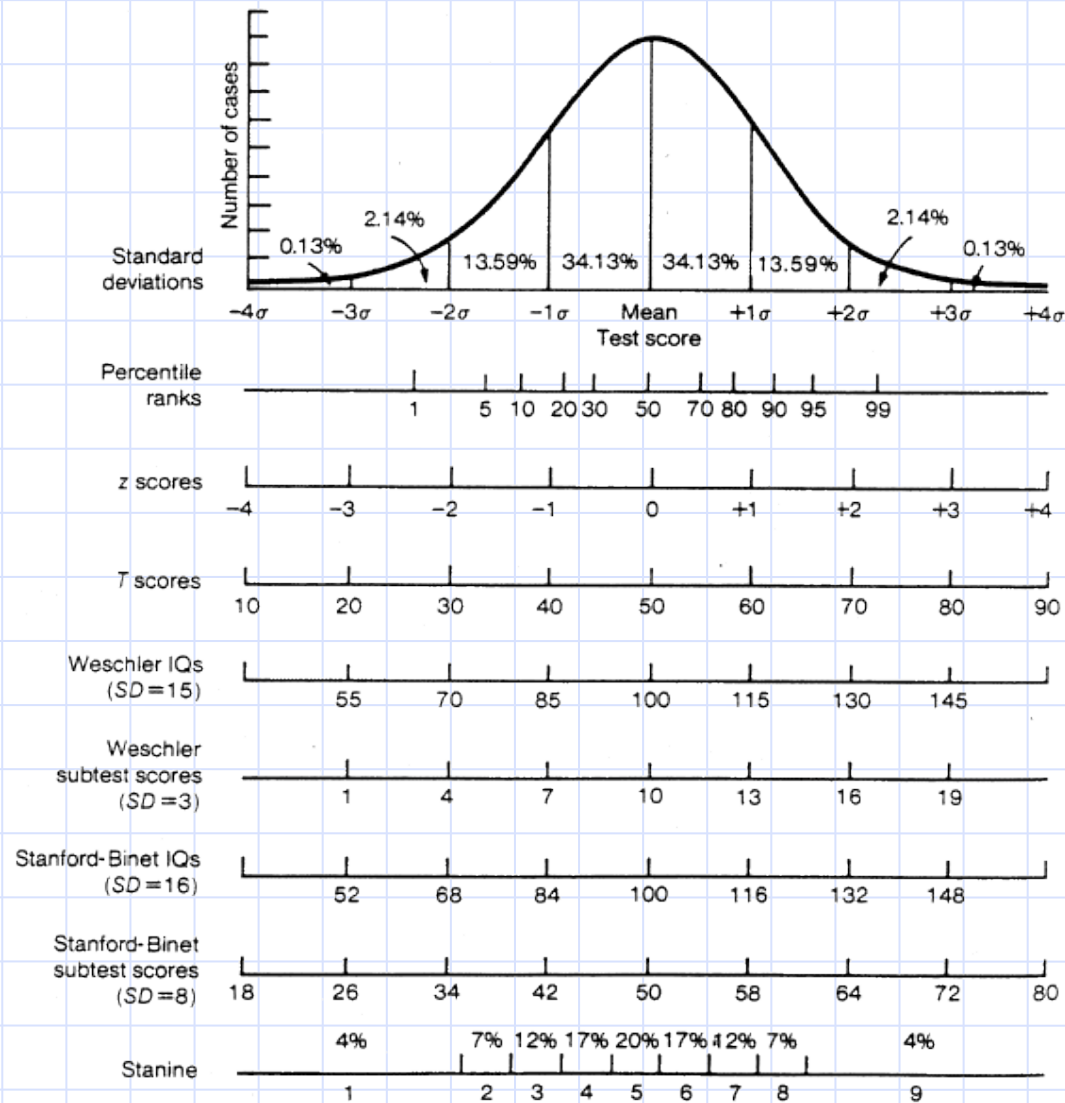


FIGURE 15-19

Sea levels. The recent global rise of sea level. [Adapted from V. Gornits, S. Lebedeff, and J. Hausen, *Science* 215 (1982): 1611-14.]

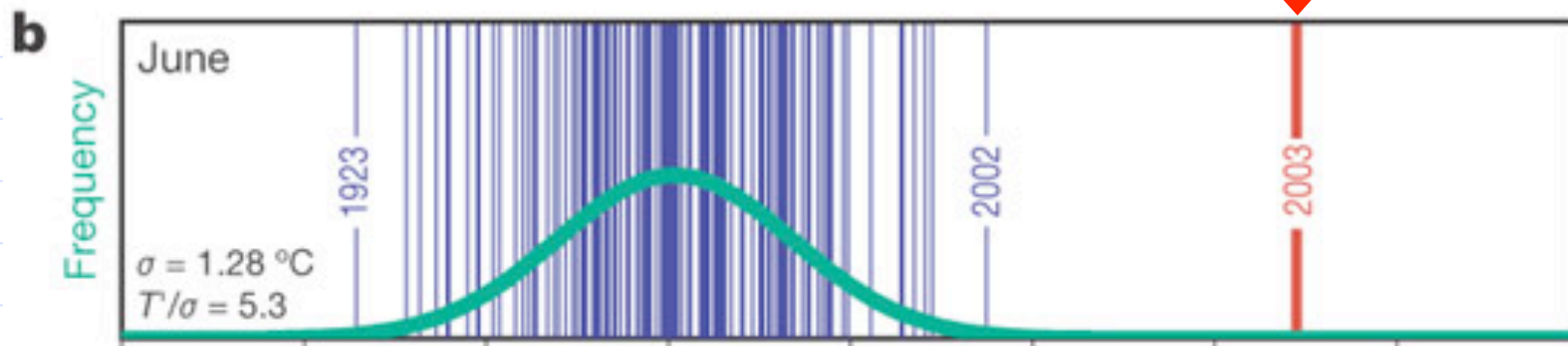


Familiar Benchmarks: IQ



Climate Change

Europe Summer Temperatures: 2003



Personal Info

Federal Taxes

Federal Review

Finish Up

Review & Plan

Error Check

Audit Support

Your Audit Risk Summary



We've reviewed your return for some common situations that have historical audit risk. [More](#)

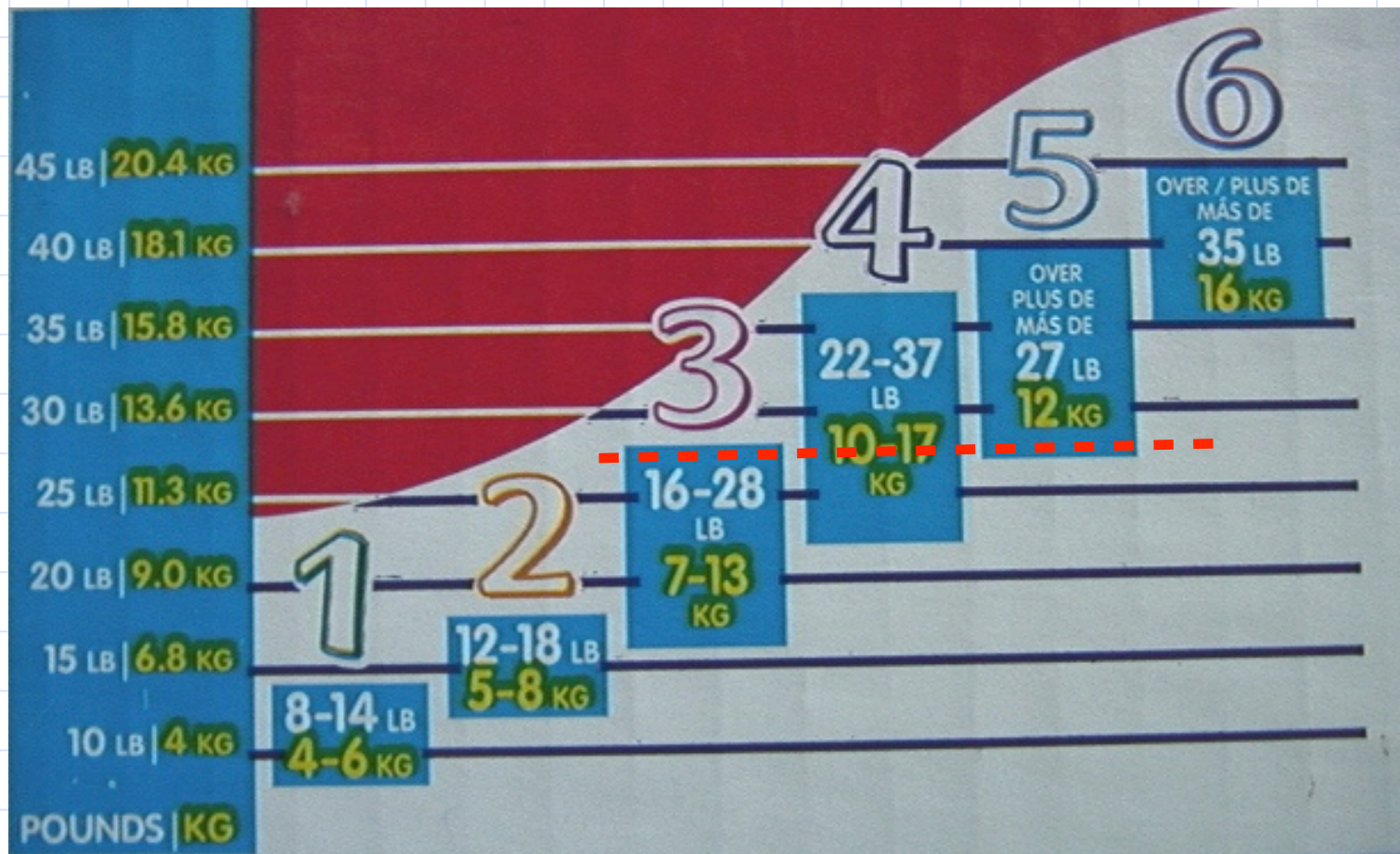
Here's what we found:

Your audit risk is medium. Please select **Show Details** to see important information from our audit risk analysis.

You have a Schedule C as part of your tax return.

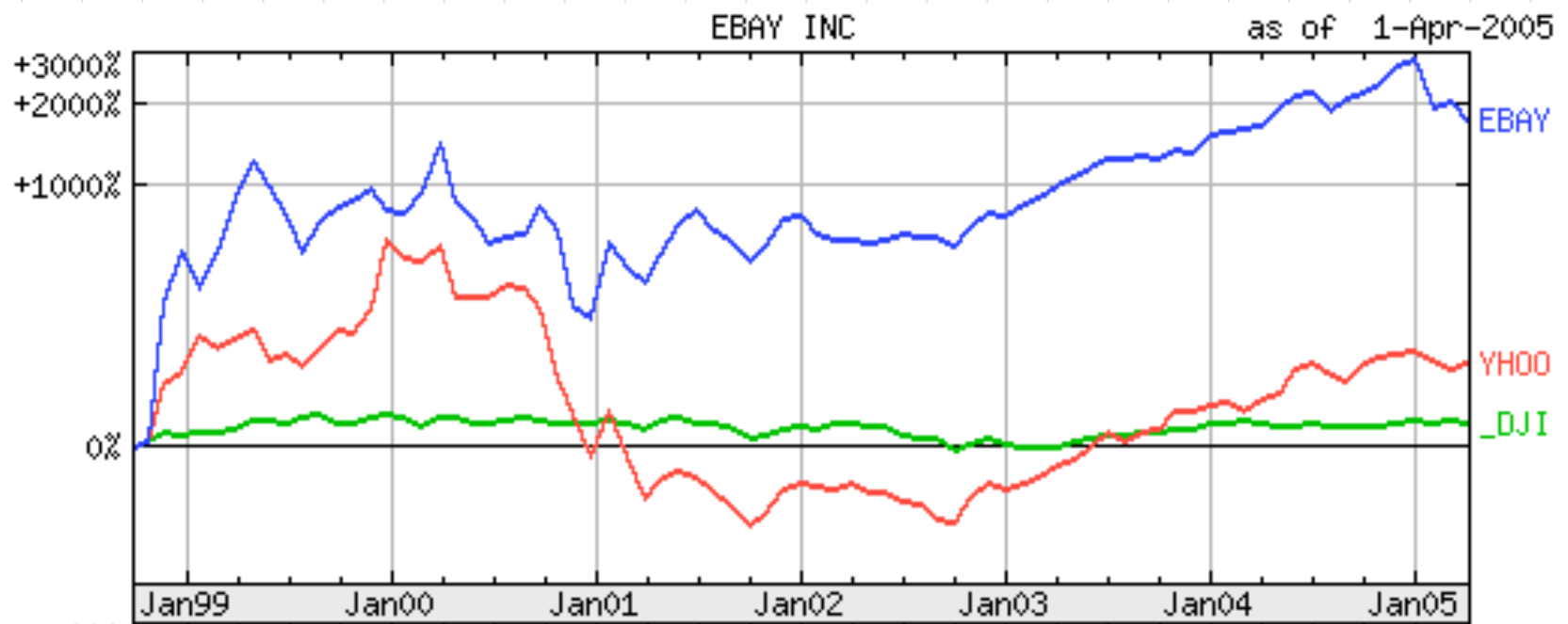
☐ Show Details

Huggies: Diaper Size as Function of Child Weight (?!@#)



Nice chart; dubious value in real world
(Do parents even pick diapers based on child's weight?)

Benchmarks are Everywhere

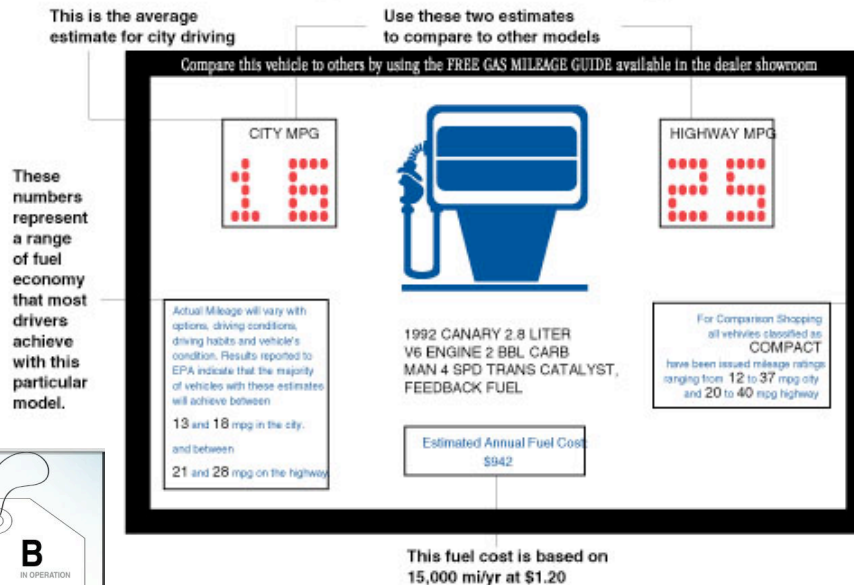


Familiar Energy Benchmarks ...

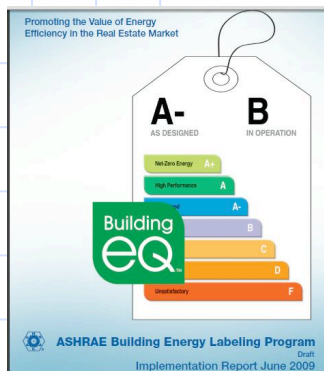
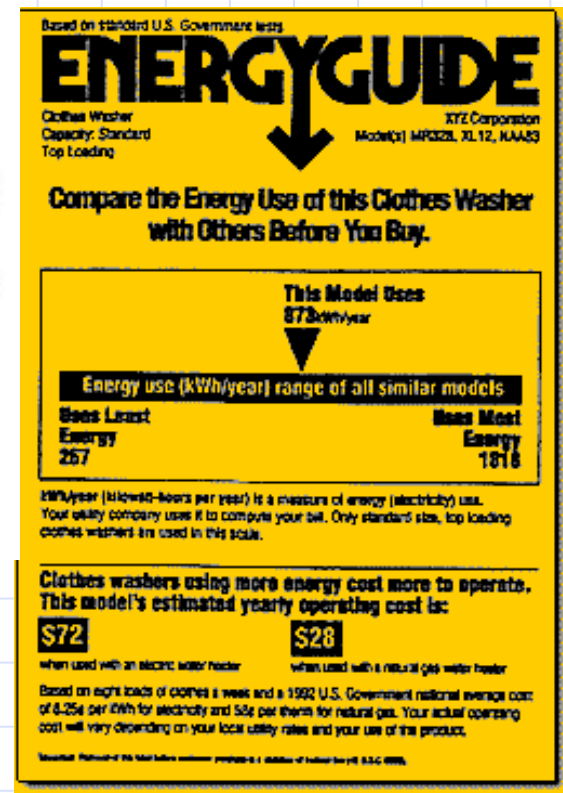
...Fundamental differences in approach



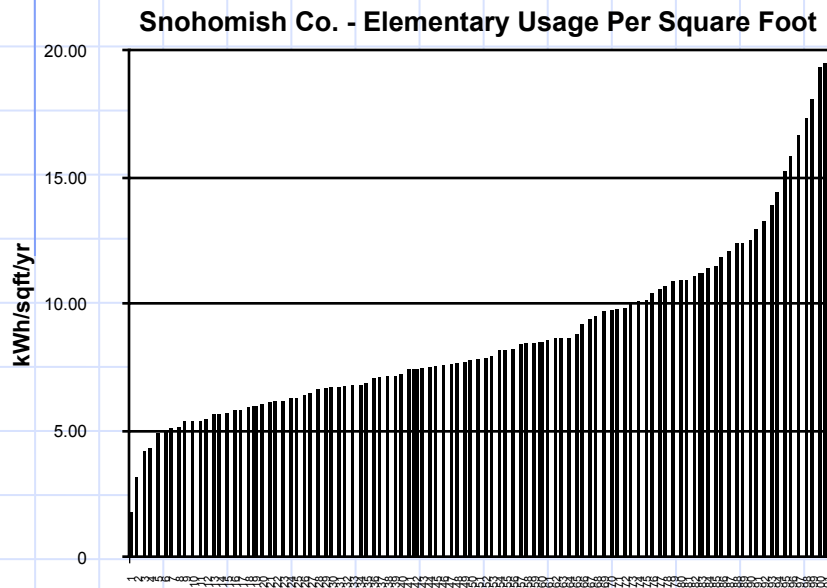
Sample Fuel Economy Label
(Attached to New Vehicle Window)



These numbers represent the range of fuel economy for other models of this size class.



Why Benchmark Energy Use?



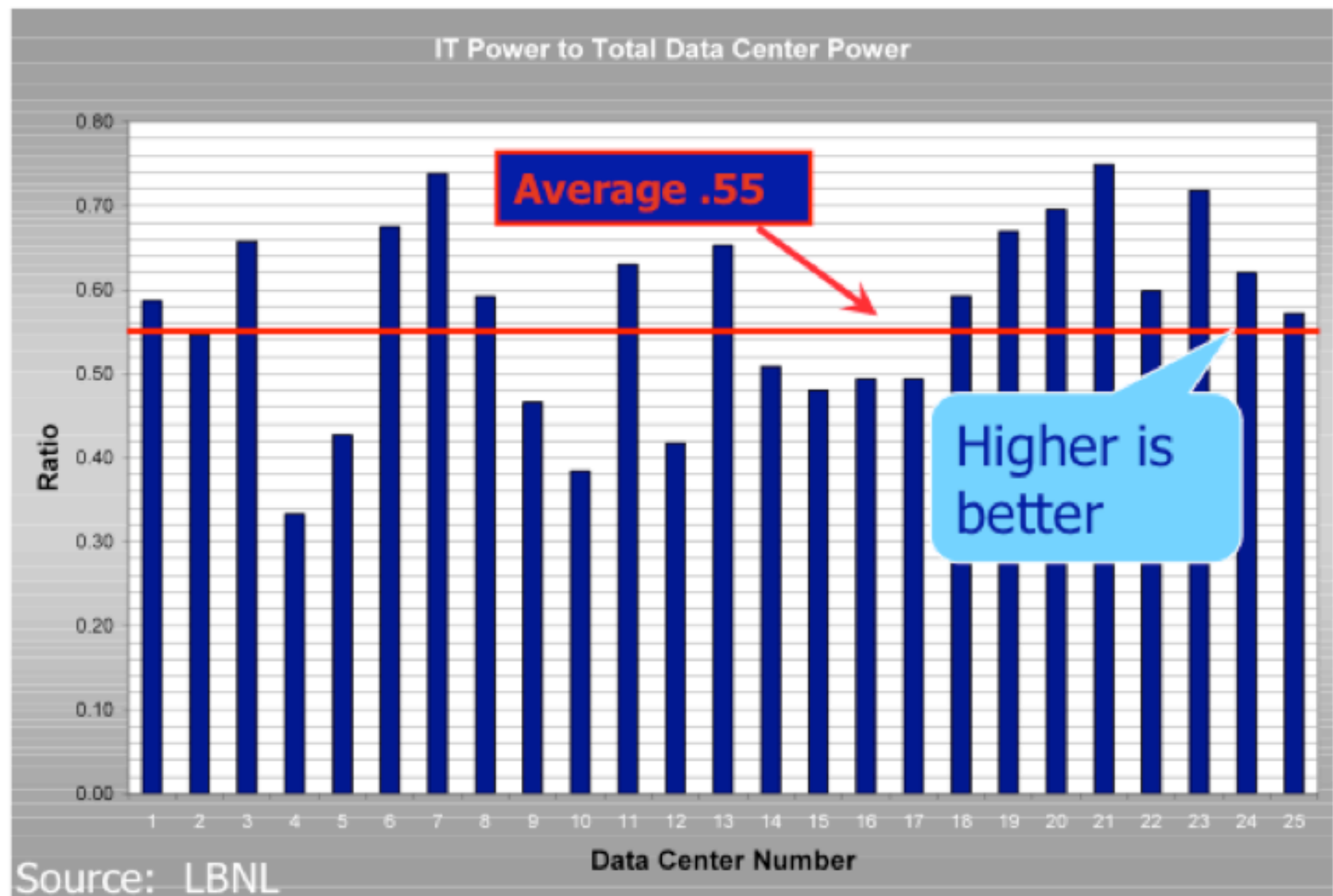
- ◆ Establish baseline and track performance
- ◆ Thumbs up/down rating
- ◆ Commission & validate design intent
- ◆ Identify best practices; set goals or standards
- ◆ Identify savings potential
- ◆ Prioritize efforts
- ◆ Identify maintenance and control problems
- ◆ Educate; Inspire; Embarrass!

Energy benchmarking is one part of a broader energy management process

Targets

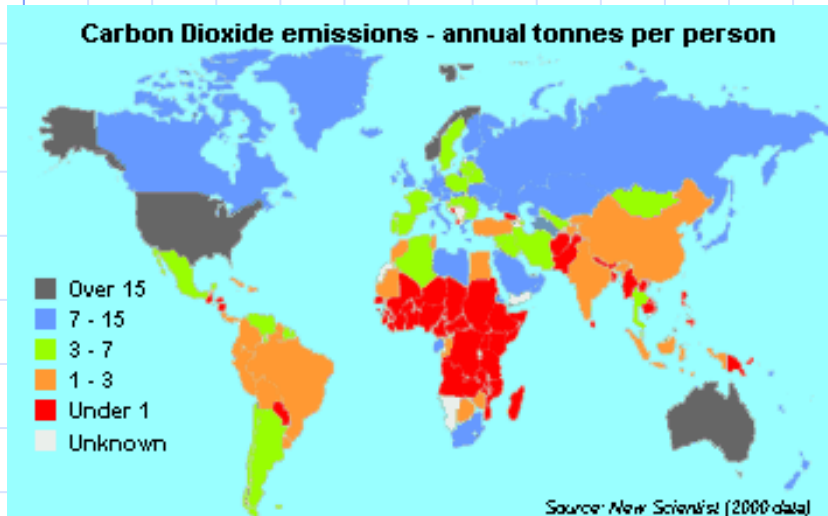


Benchmarks Can Provide a “Reality Check” for planners



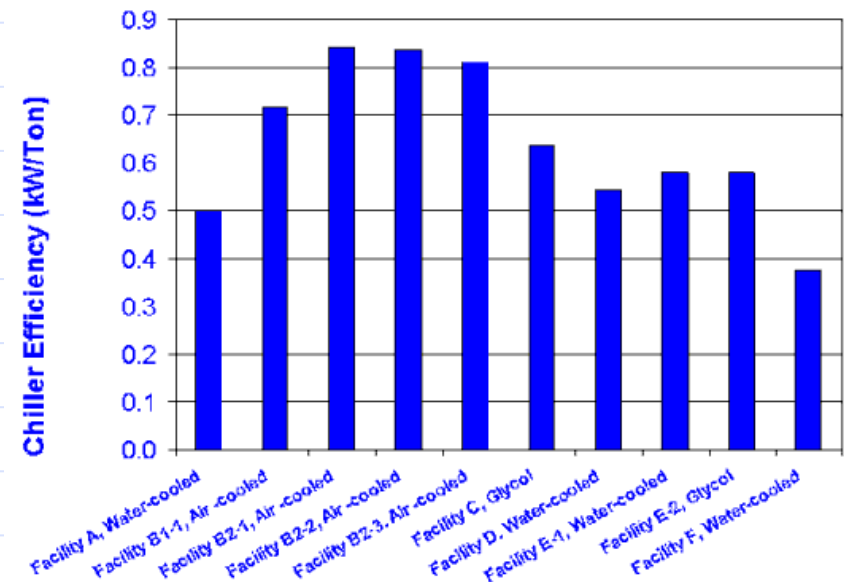
Benchmarking Can Be Done at Any Scale

Global CO₂/Capita

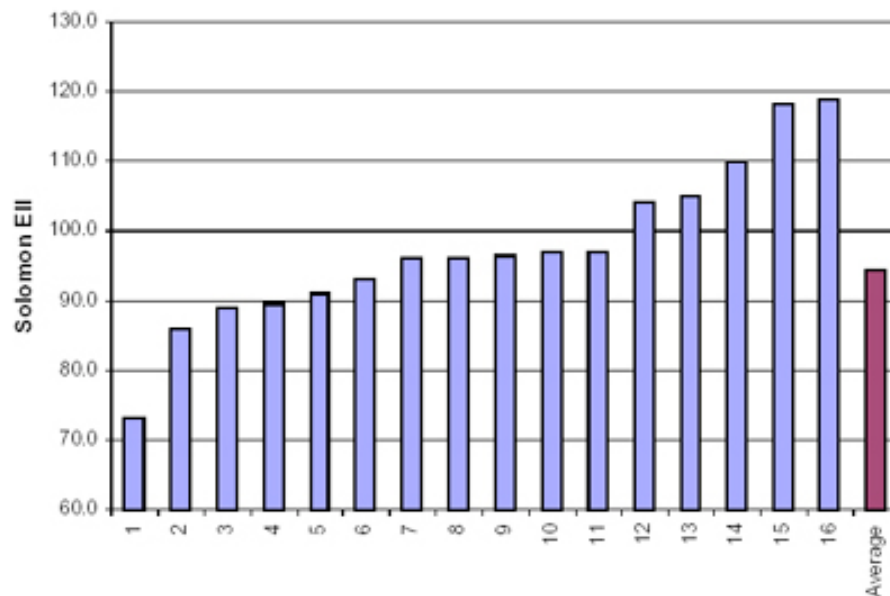


Chiller efficiency

Chiller efficiency (Power demand of chiller per unit of cooling generated). Figure 8 illustrates the measured chiller efficiencies in ten of the facilities in this project where central plant data was obtained. For this metric, lower values indicated better energy efficiency. These chillers often serve multiple cleanrooms as well as other parts of the facility.



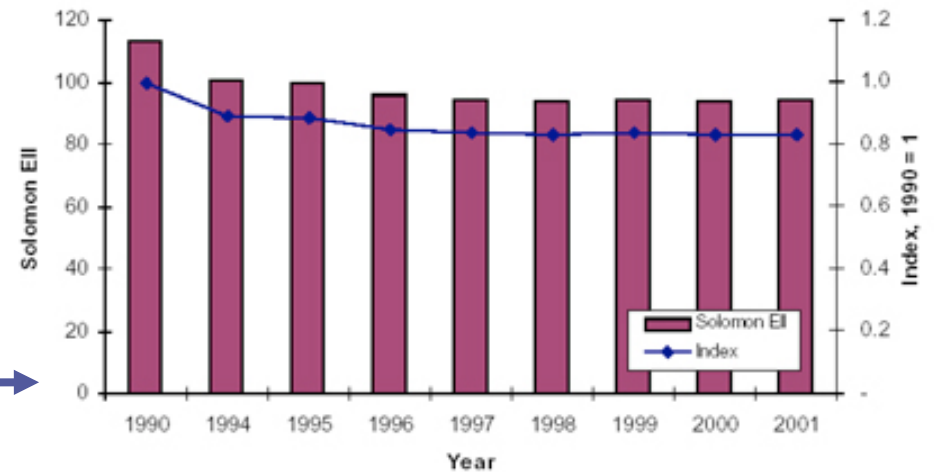
Lateral vs. Longitudinal: e.g. Oil Refineries



Solomon Energy Intensity Index of Participating Individual Refineries
Source: CIEEDAC, 2002.

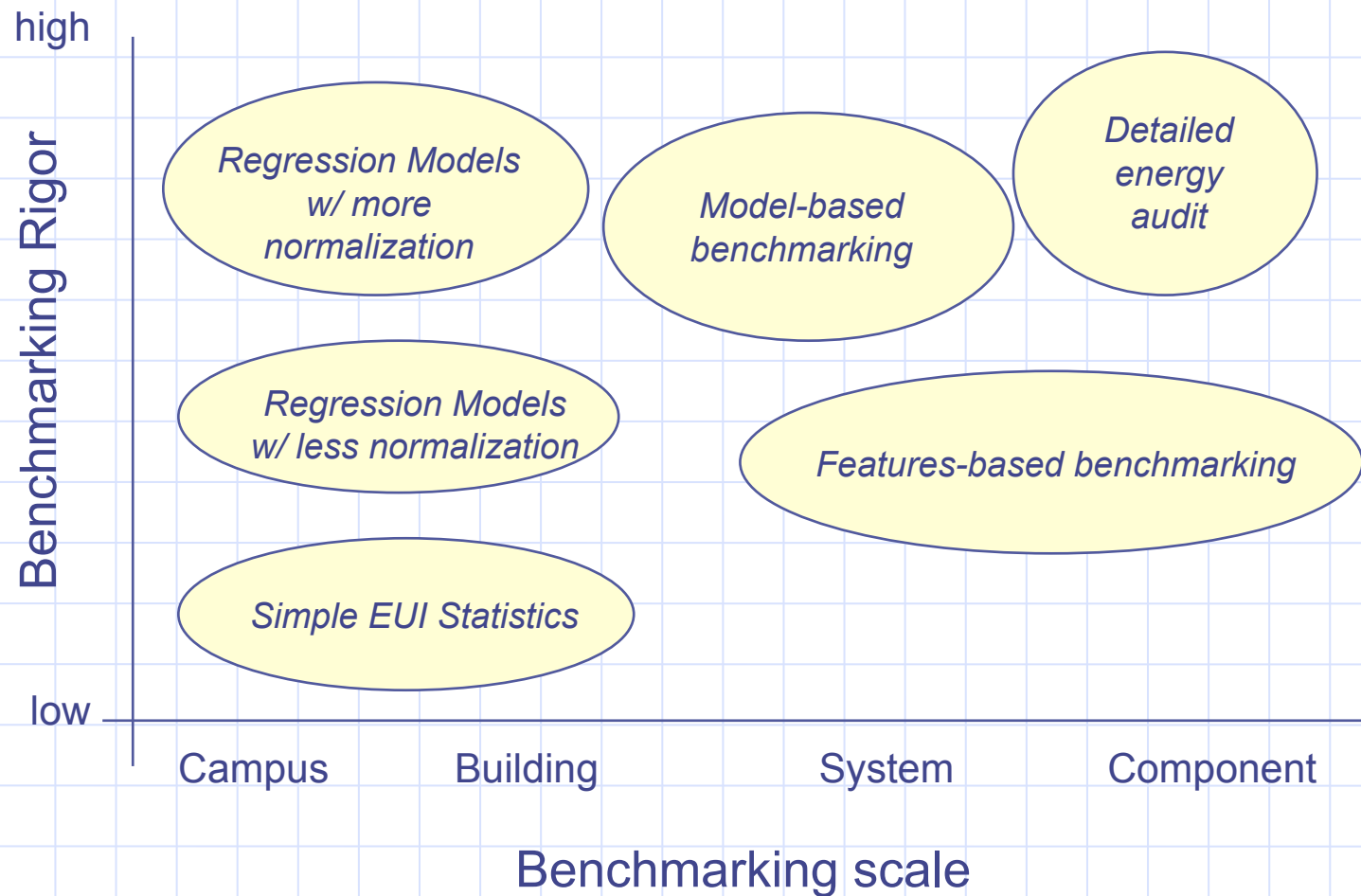
Comparing “peers” at
one point in time

Following “fleet-wide”
trends over time



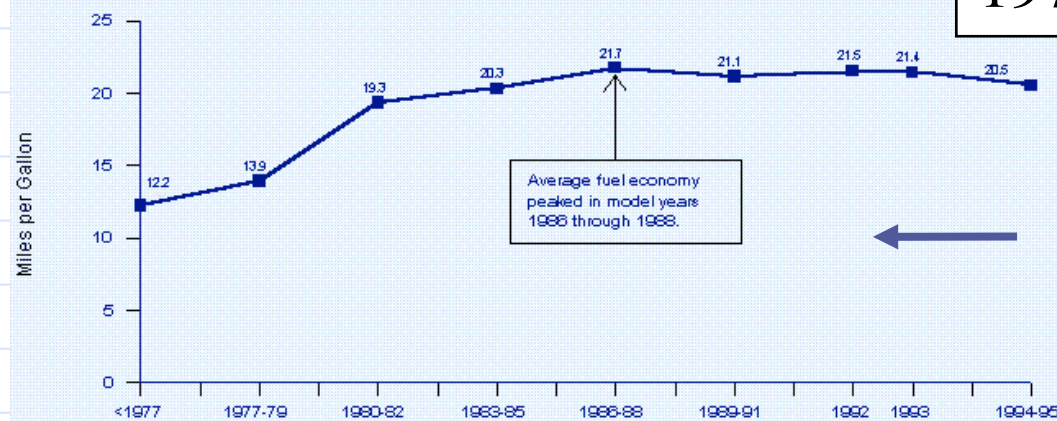
Average Refinery Energy Intensity based on a composite of Solomon EII for all known refineries.⁴

Approach to benchmarking depends on the purpose



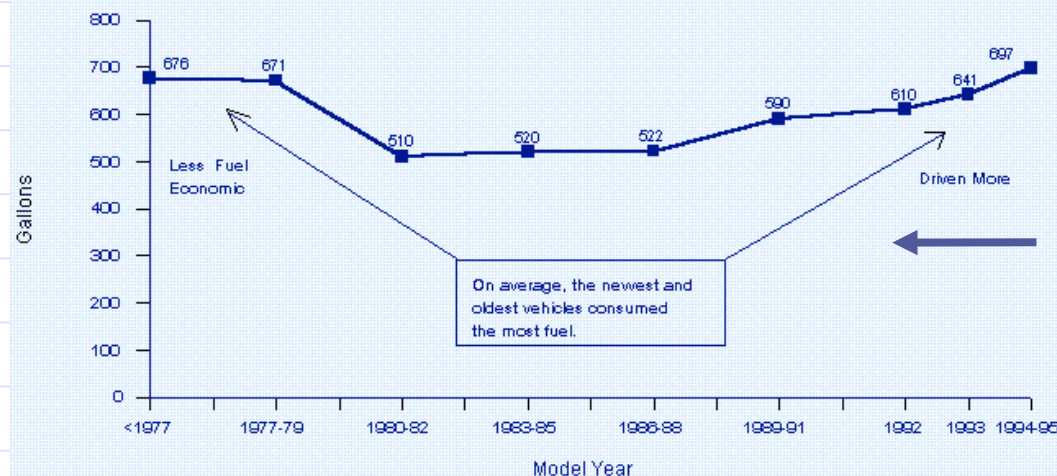
Choice of Benchmark Determines Conclusion

Figure 4.1 Average Fuel Economy of Residential Vehicles for Model Years Through 1995



Average US fuel economy increasing, then flat

Figure 4.9 Average Residential Vehicle Fuel Consumption per Vehicle for Model Years Through 1995

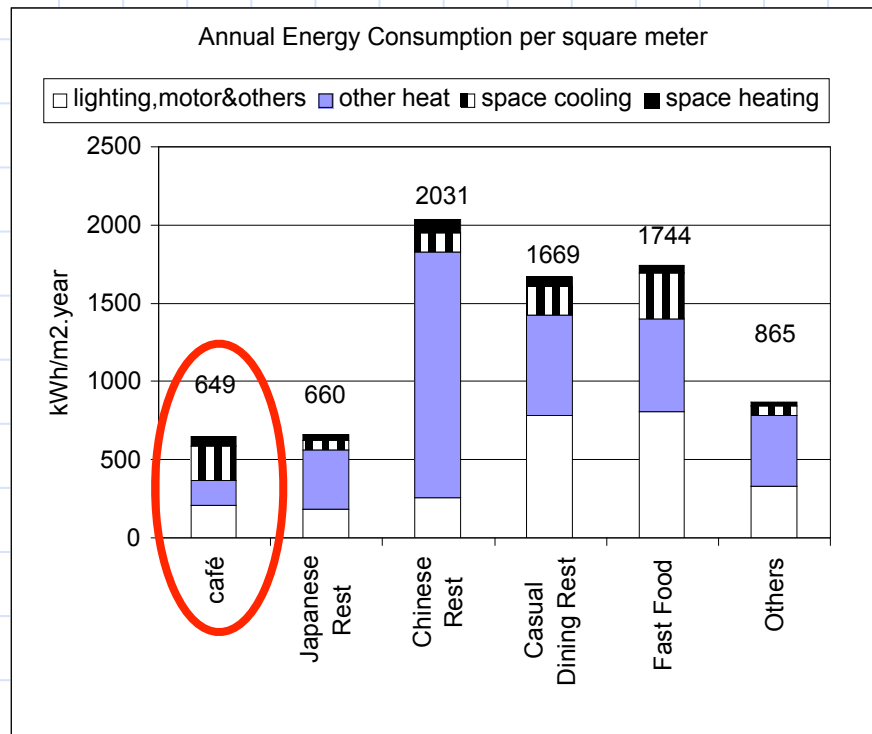


Average US vehicle fuel use declining, then rising

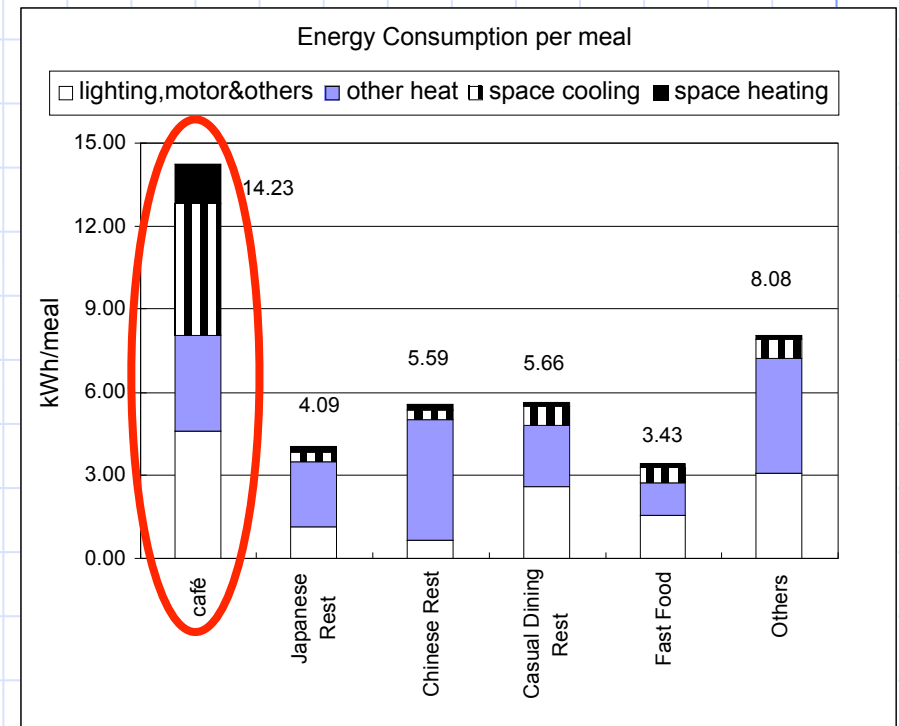
Source: USDOE/EIA

Choice of Indicator is Key

Energy per unit floor area



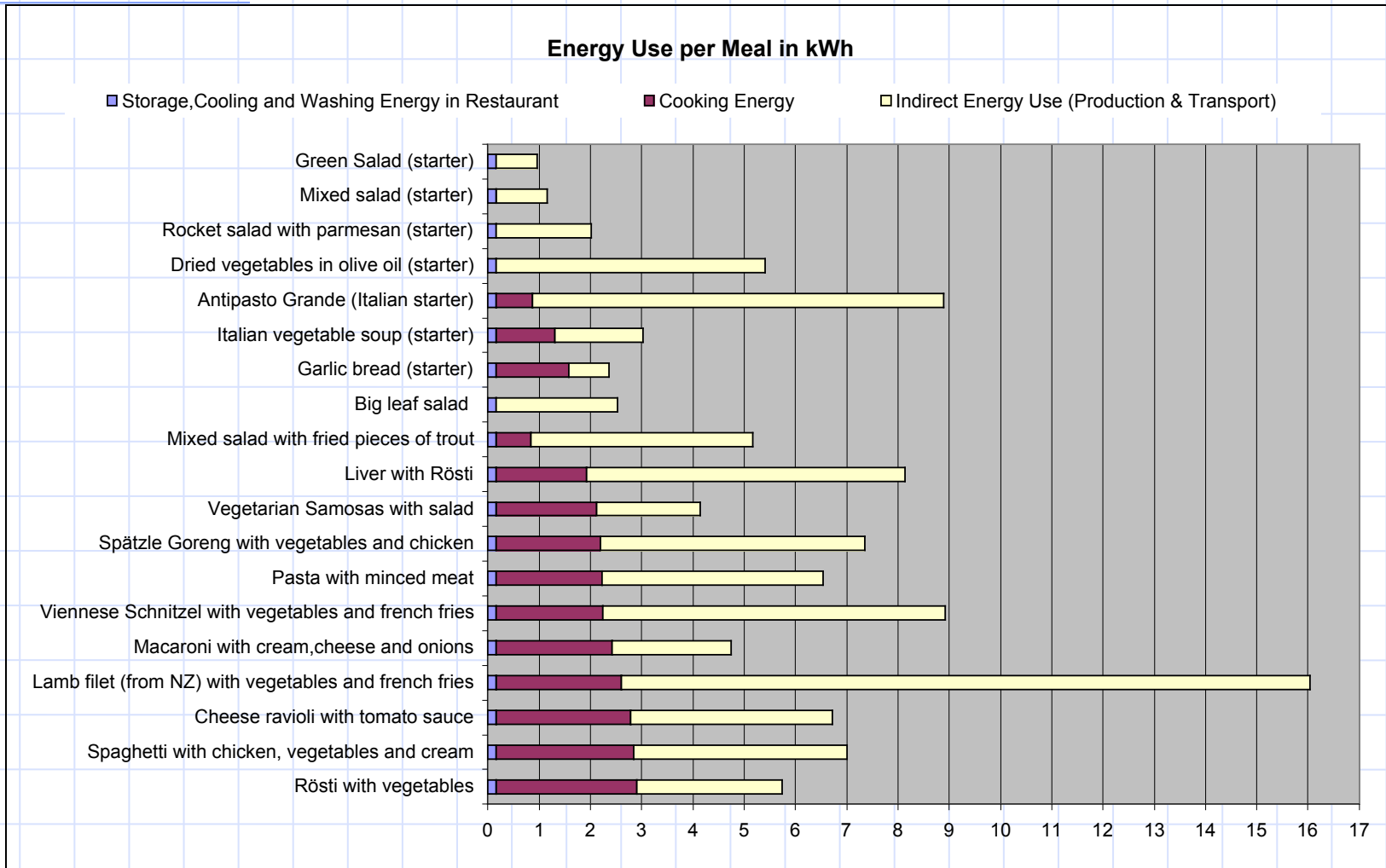
Energy per meal



Café ranks “best” by one benchmark and “worst” by the other

Source: The Energy Data and Modeling Center, 2001

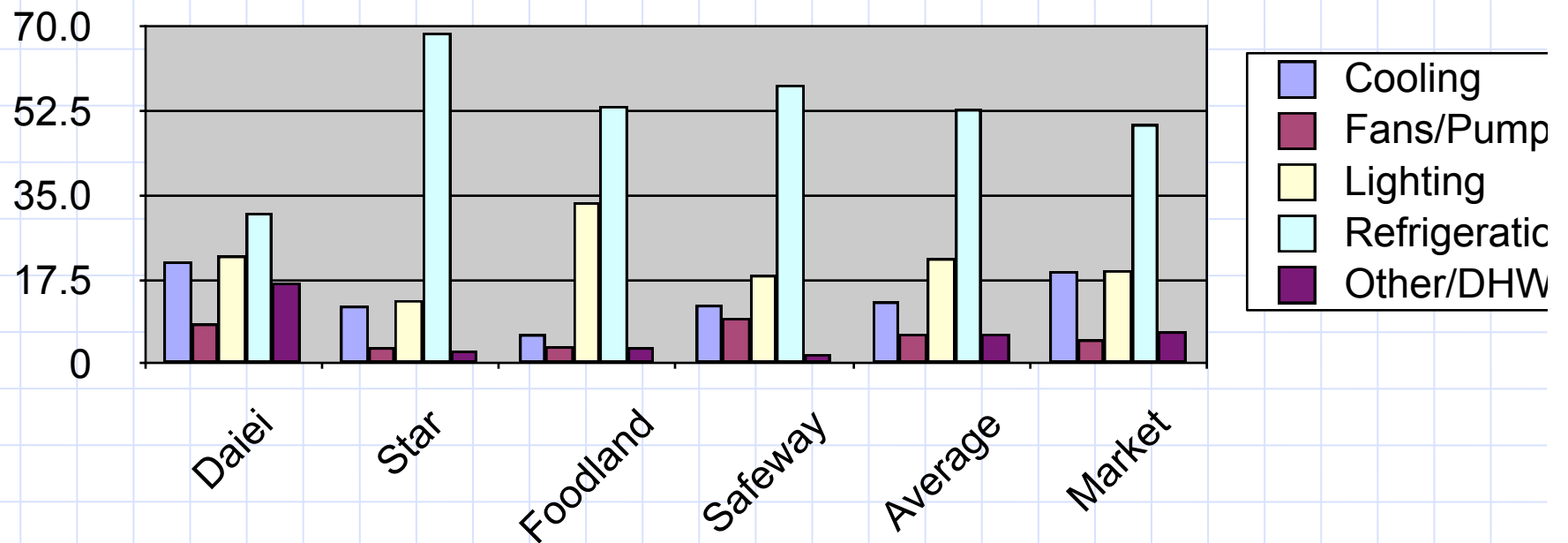
Beyond “Apples & Oranges”: Pippins and Granny Smiths



Data for Switzerland. Source: Balmer and Hintermann, 2000

End-Use Intensities

Hawaiian Grocery Stores (kWh/ft²-year)



Source: HECO, Thomas D. Van Liew

Intensities x Enterprise

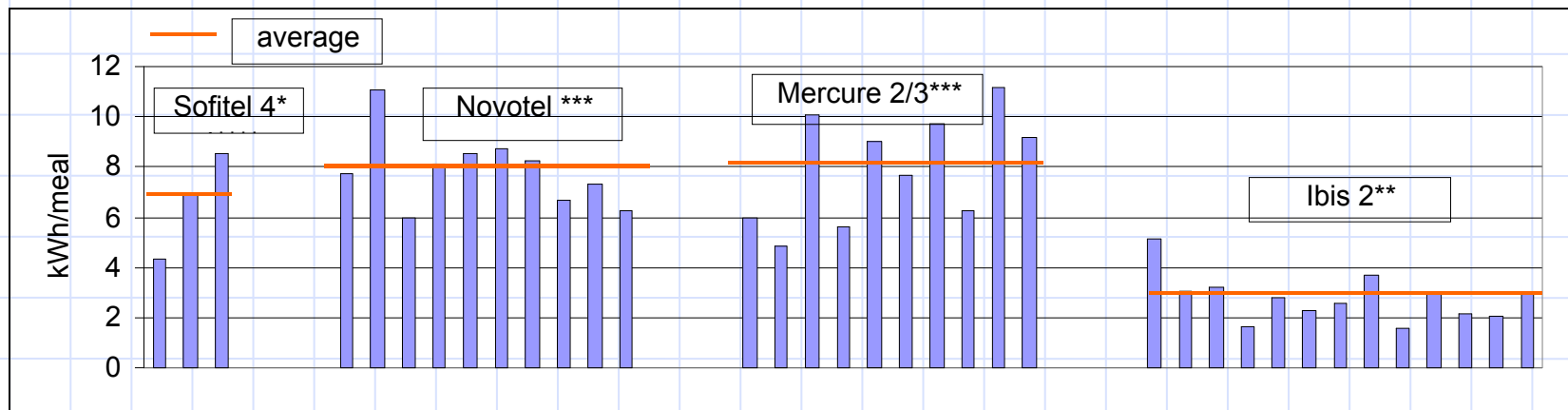
Energy per meal for 36 hotels, France

Std. Dev. 34%

27%

19%

32%

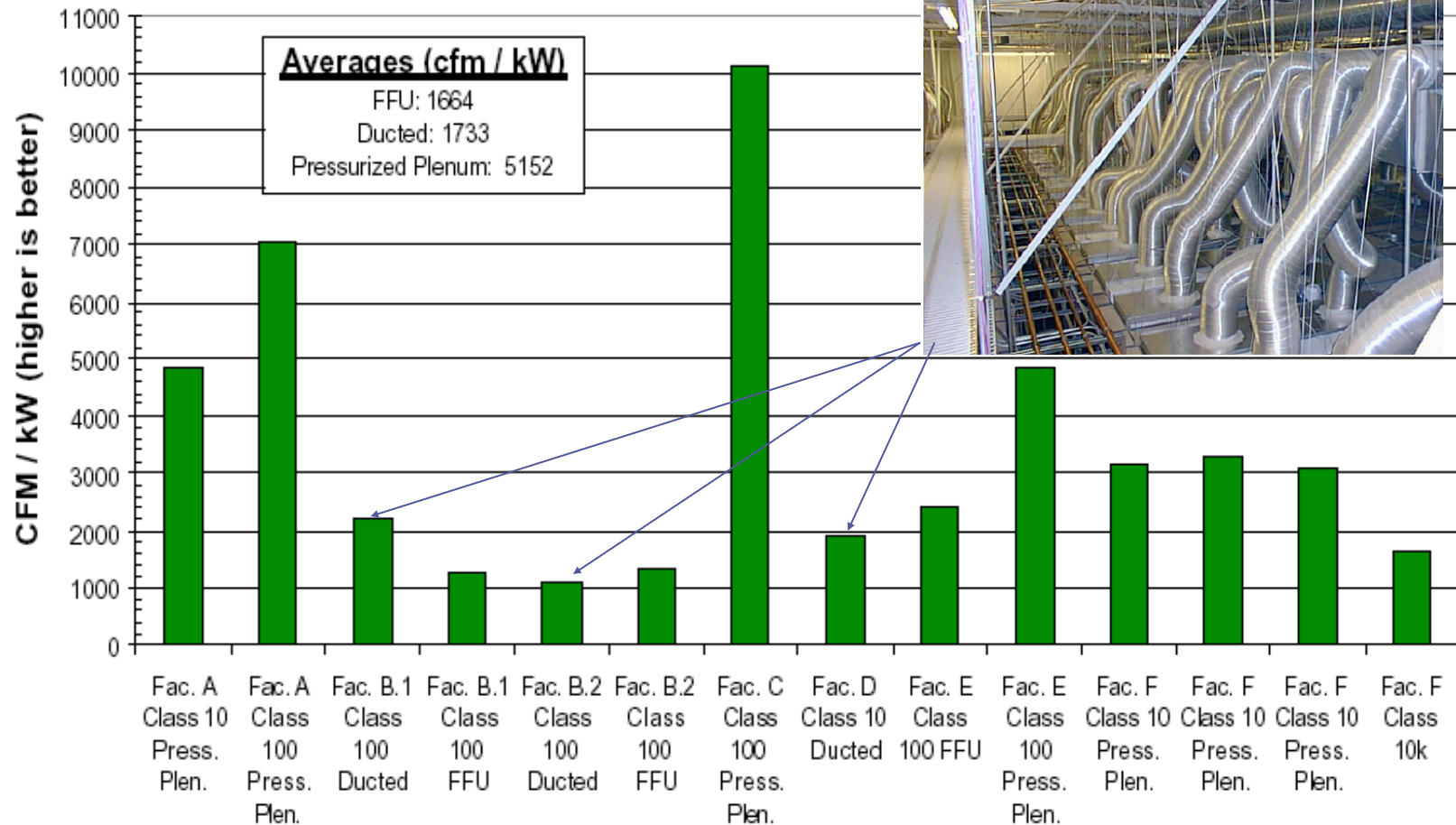


category of hotels	conservation kWh/meal	cooking kWh/meal	dishwashing kWh/meal	total kWh/meal	standard deviation
2**	0.44	2.08	0.25	2.77	0.94
2**/3***	3.81	3.89	0.25	7.95	2.18
3***	3.67	3.99	0.21	7.86	1.47
4****	2.53	3.92	0.13	6.58	2.13

Source: Le Strat et al., (1999)

Delivery of Service Levels: Cleanrooms

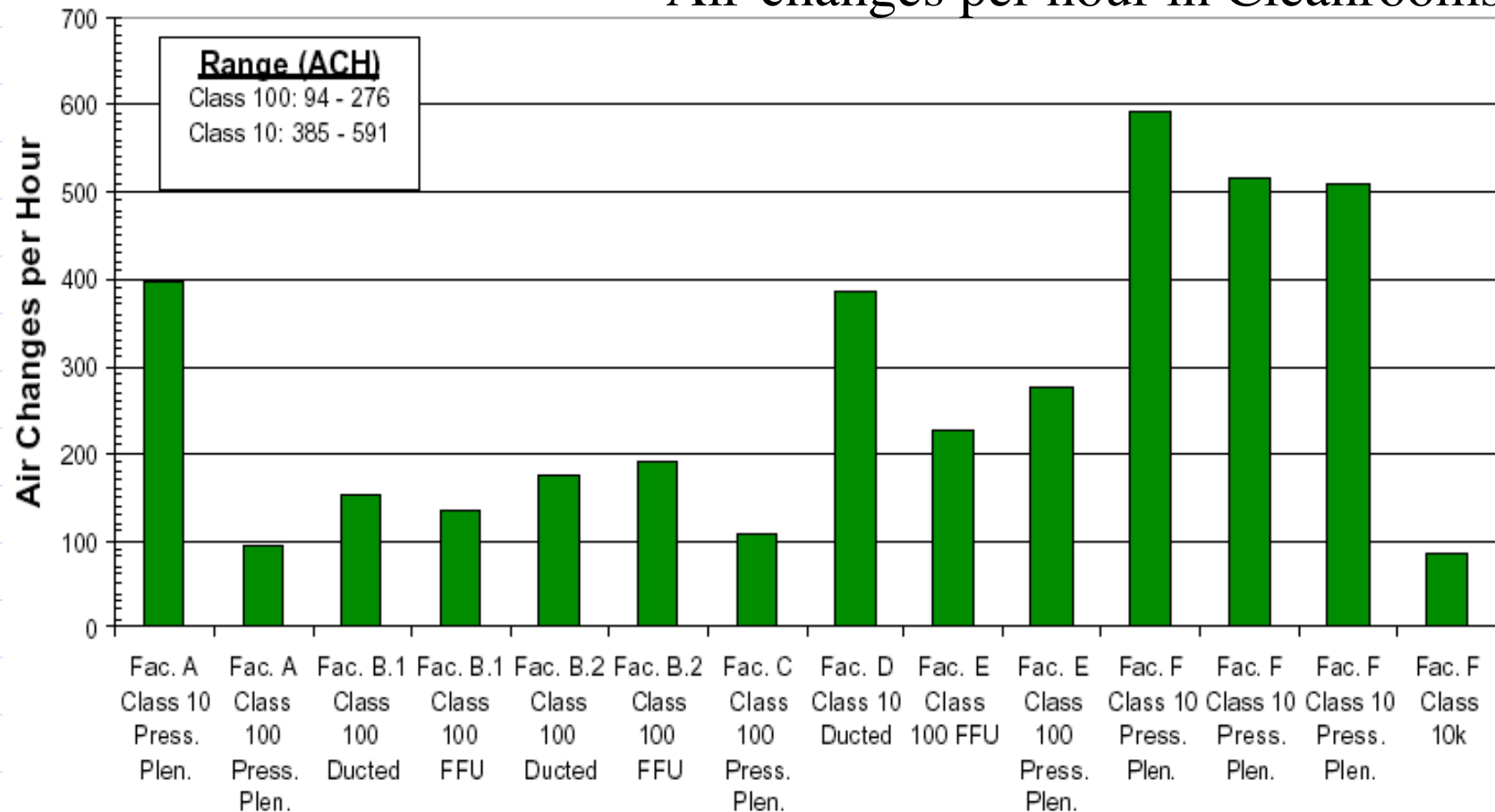
Air movement CFM/kW (higher is better)



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

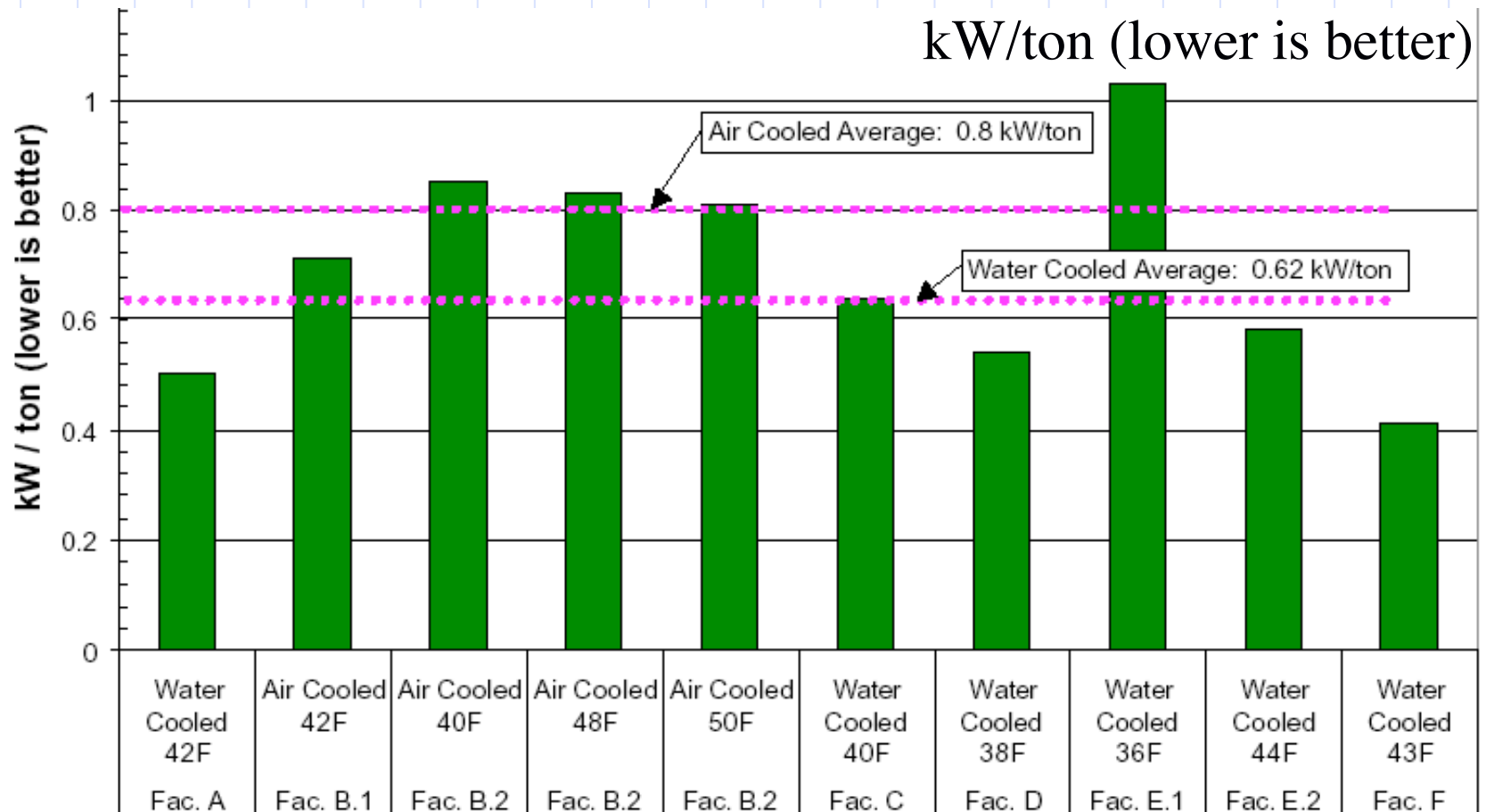
Some “Energy” Benchmarks Don’t Even Include Energy

Air-changes per hour in Cleanrooms



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

Component Benchmarking: Cleanroom Chiller Efficiencies



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

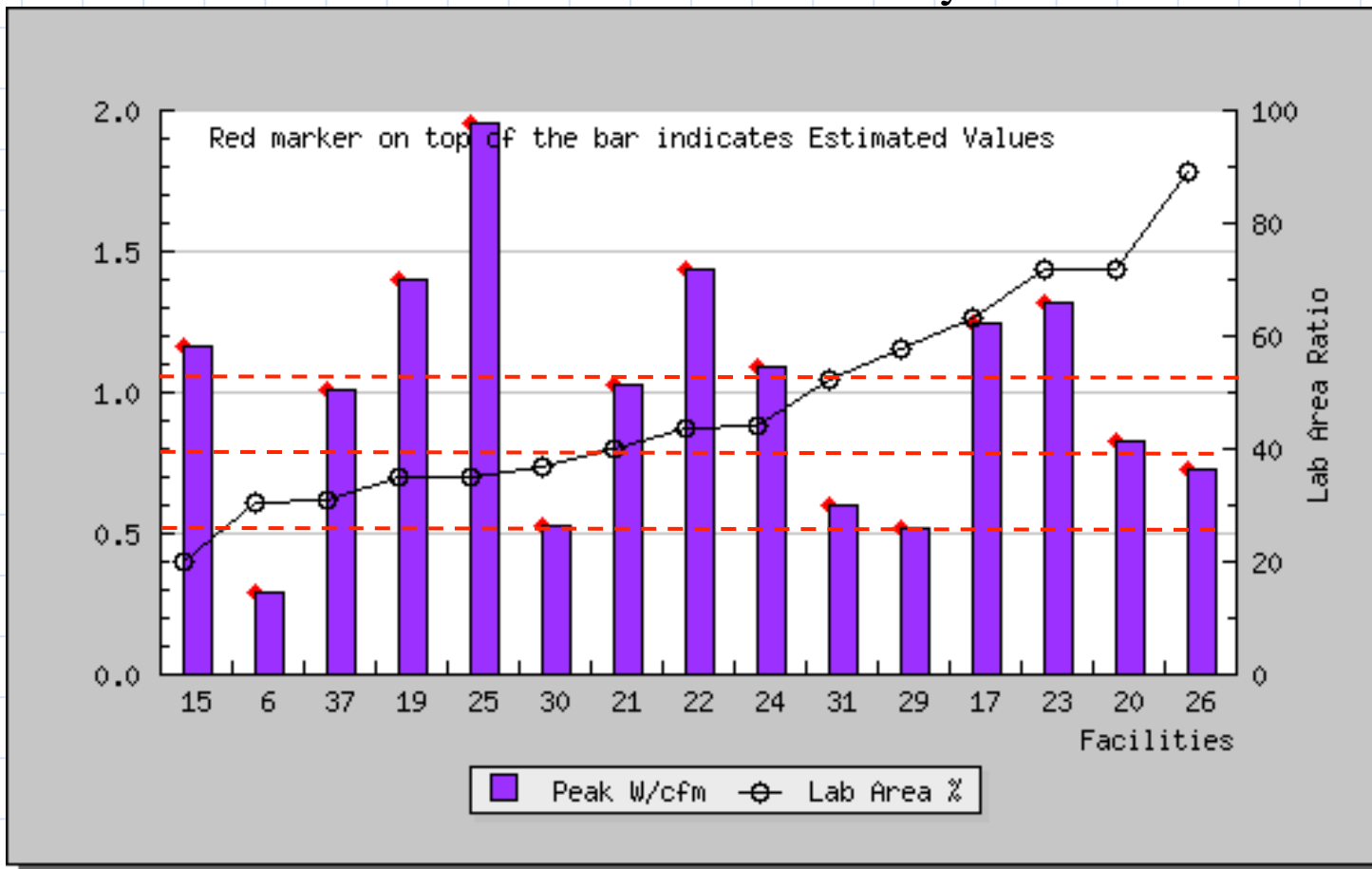
Cleanroom Energy Metrics

•Recirculation air handler efficiency	•cfm/kW
•Makeup air handler efficiency	•cfm/kW
•Annual energy cost per cleanroom square foot	•\$/ft ²
•Annual fuel usage	•MBtu/ft ² -yr
•Annual electricity usage	•kWh/ft ² -yr
•Annual energy usage	•MBtu/ft ² -yr
•Makeup air	•cfm/ft ²
•Recirculation air	•cfm/ft ² or ach
•Chiller efficiency	•kW/ton
•Tower efficiency	•kW/ton
•Condenser water pump efficiency	•kW/ton
•Chilled water pump efficiency	•kW/ton
•Total chilled-water plant efficiency	•kW/ton
•Hot water pumping efficiency	•kW/MBtu
•Cooling load density	•ft ² /ton

Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

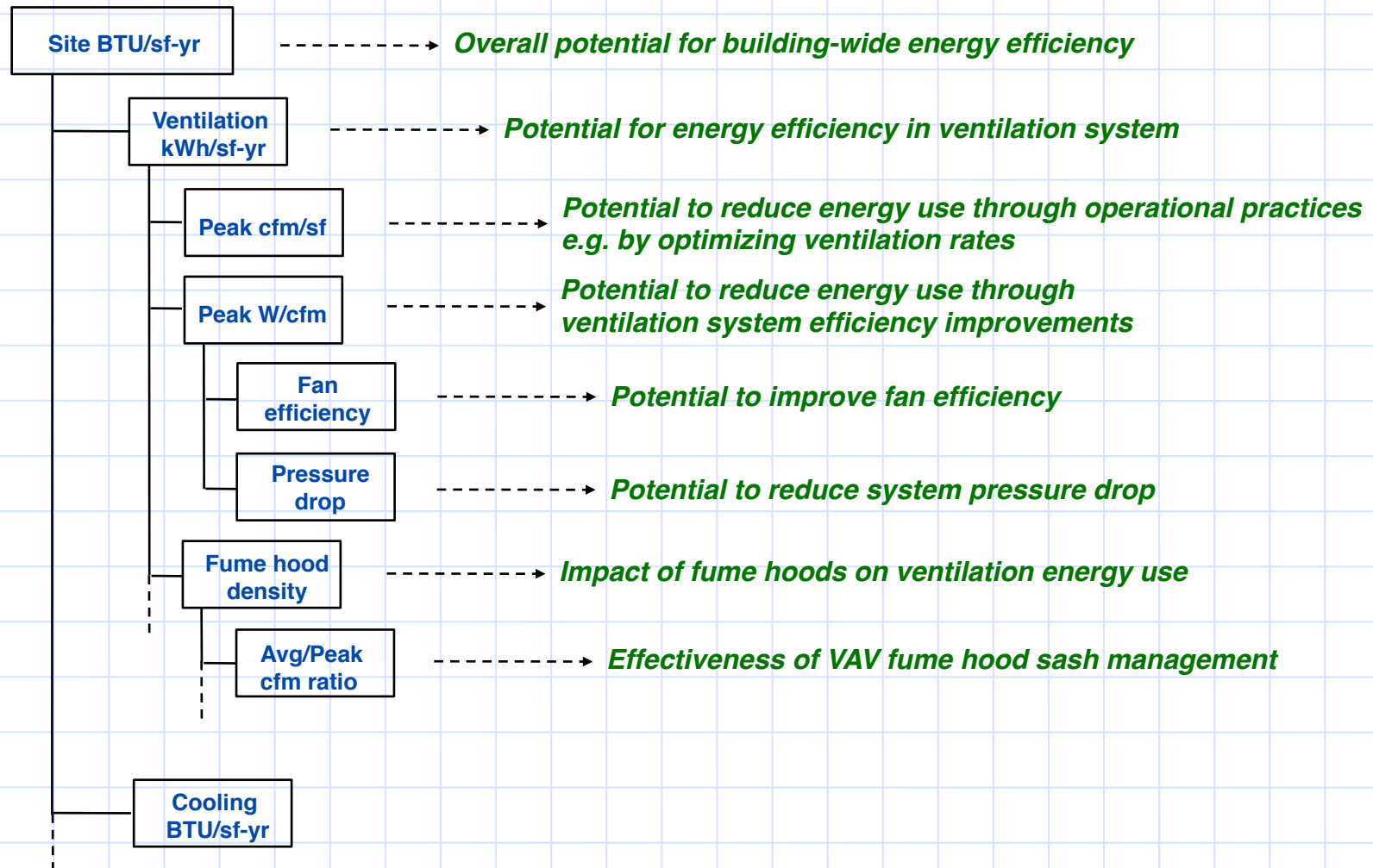
From Benchmarking to Best Practices

Laboratory Ventilation W/cfm



Standard, good, better benchmarks as defined in
"How-low Can You go: Low-Pressure Drop Laboratory Design"
by Dale Sartor and John Weale, ASHRAE Journal

Action-oriented Benchmarking



Action-oriented benchmarking

Compliments other assessments

Whole Building Energy Benchmarking

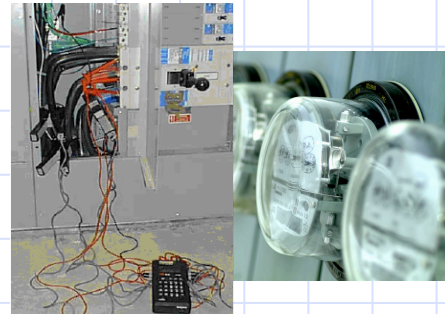


Screen facilities for overall potential

0.5-2 day FTE

Minimal data requirements (utility bills, building features)

Action-oriented Energy Benchmarking



Identifies and prioritizes specific opportunities

2-10 day FTE

Requires sub-metered end-use data ; may require additional data logging

Highly applicable for RCx and CCx

Investment-Grade Energy Audit



Estimates savings and cost for specific opportunities

10-20 day FTE

Requires detailed data collection, cost estimation, financial analysis

Necessary for retrofits with capital investments



EnergyIQ

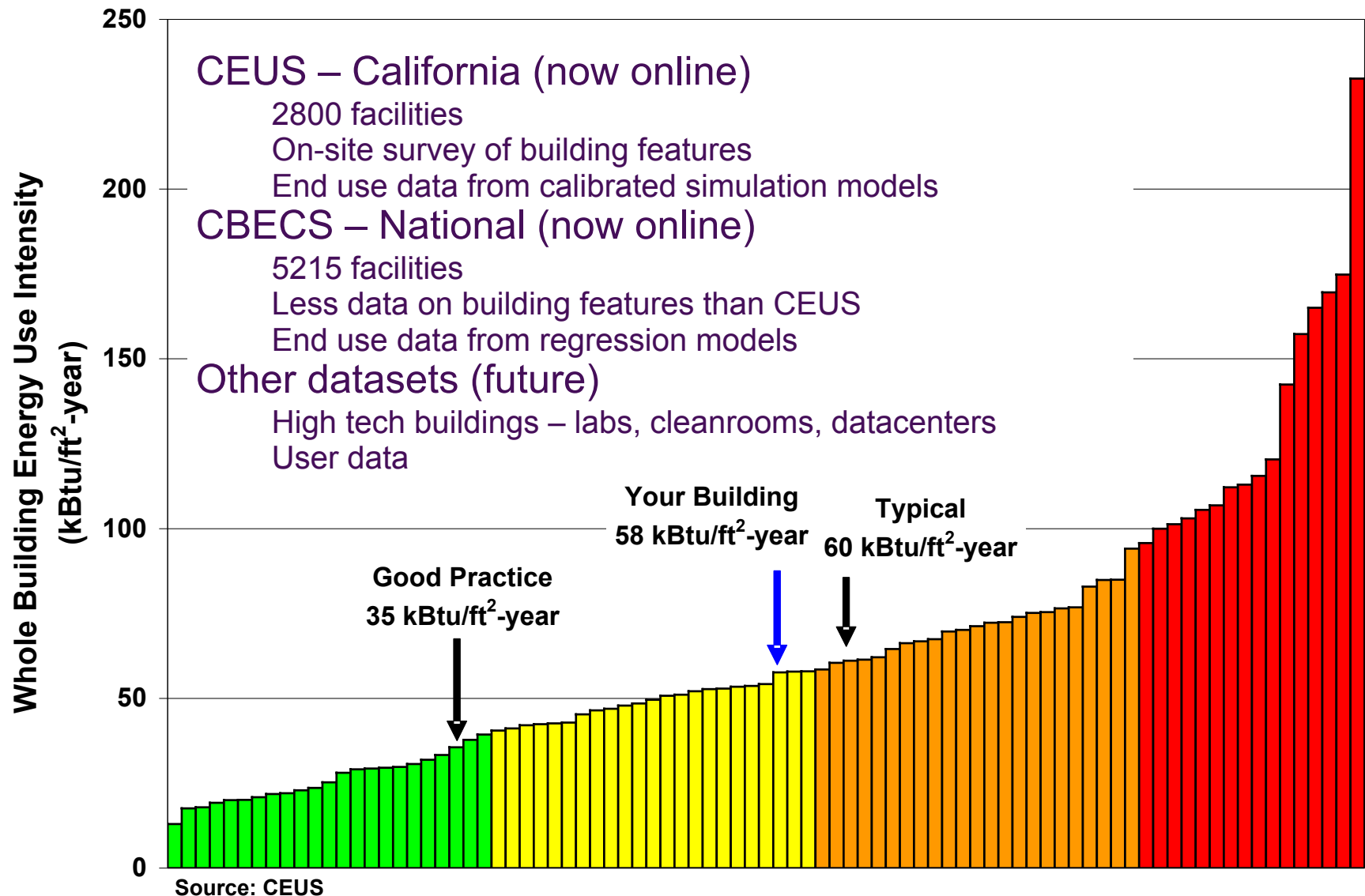
The logo features the word "EnergyIQ" in a sans-serif font. "Energy" is in a light green color, and "IQ" is in a dark purple color. A light gray sine wave is positioned behind the text, starting from the left, peaking over the "y" in "Energy", and ending with a small arrowhead pointing to the right, passing through the "Q" in "IQ".

EnergyIQ Services

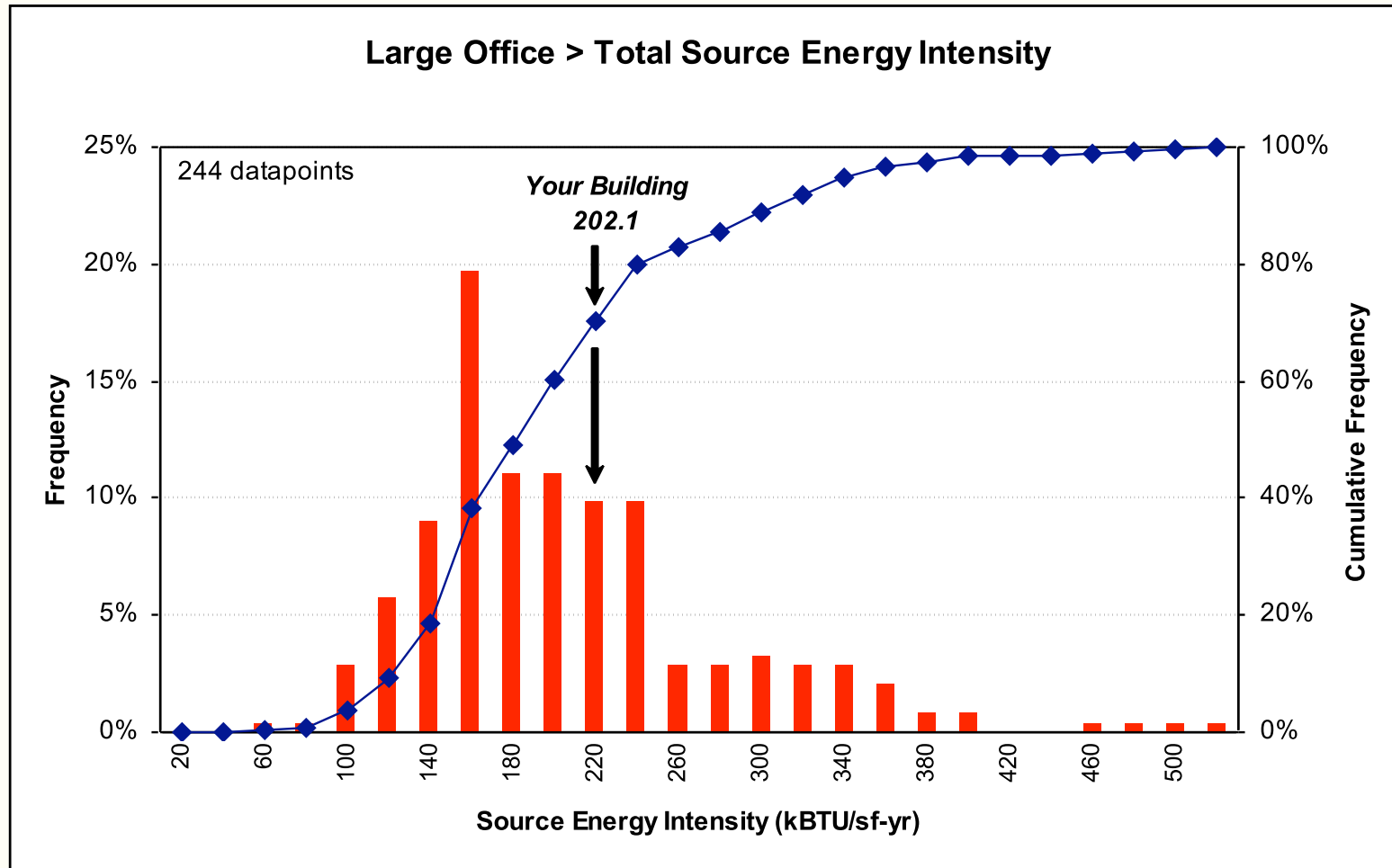
Onion-layer approach (more input = more feedback)

- Cross-sectional (current) and Longitudinal (historical) benchmarking and trending
- Handle portfolios of projects and evaluate performance *within* an enterprise
- Batch upload of pre-existing data (incl. from E*/PM)
- Export of results to Excel
- User-defined facility boundaries, metrics, targets
- High-level “roll-up” dashboards for upper-managers
- Evergreen log of “implemented” measures as well as “recommended”, and “rejected” ones
- APIs and web services for 3rd-party web developers

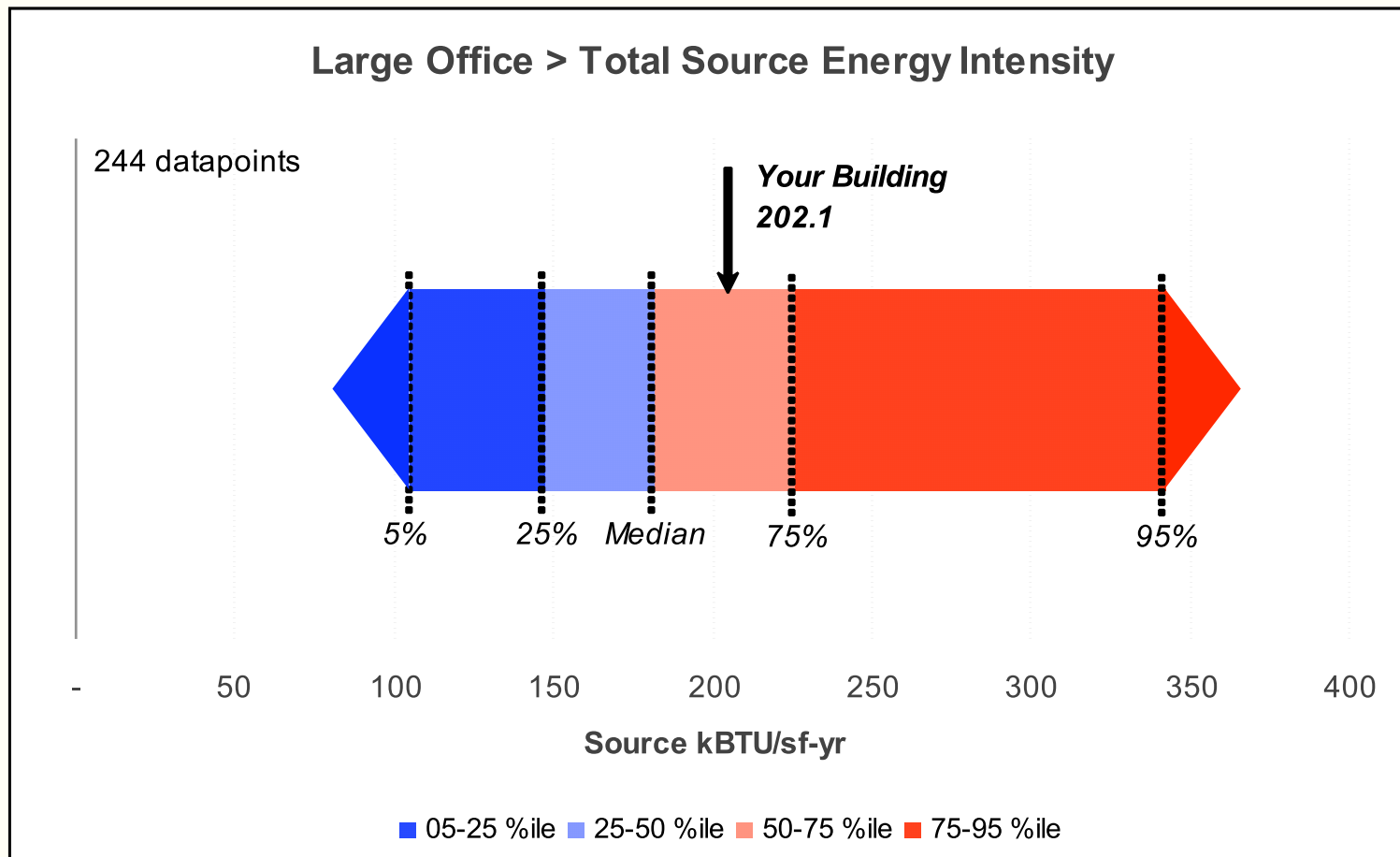
Peer-comparison datasets



Whole Building Energy Intensity → Overall Efficiency Potential

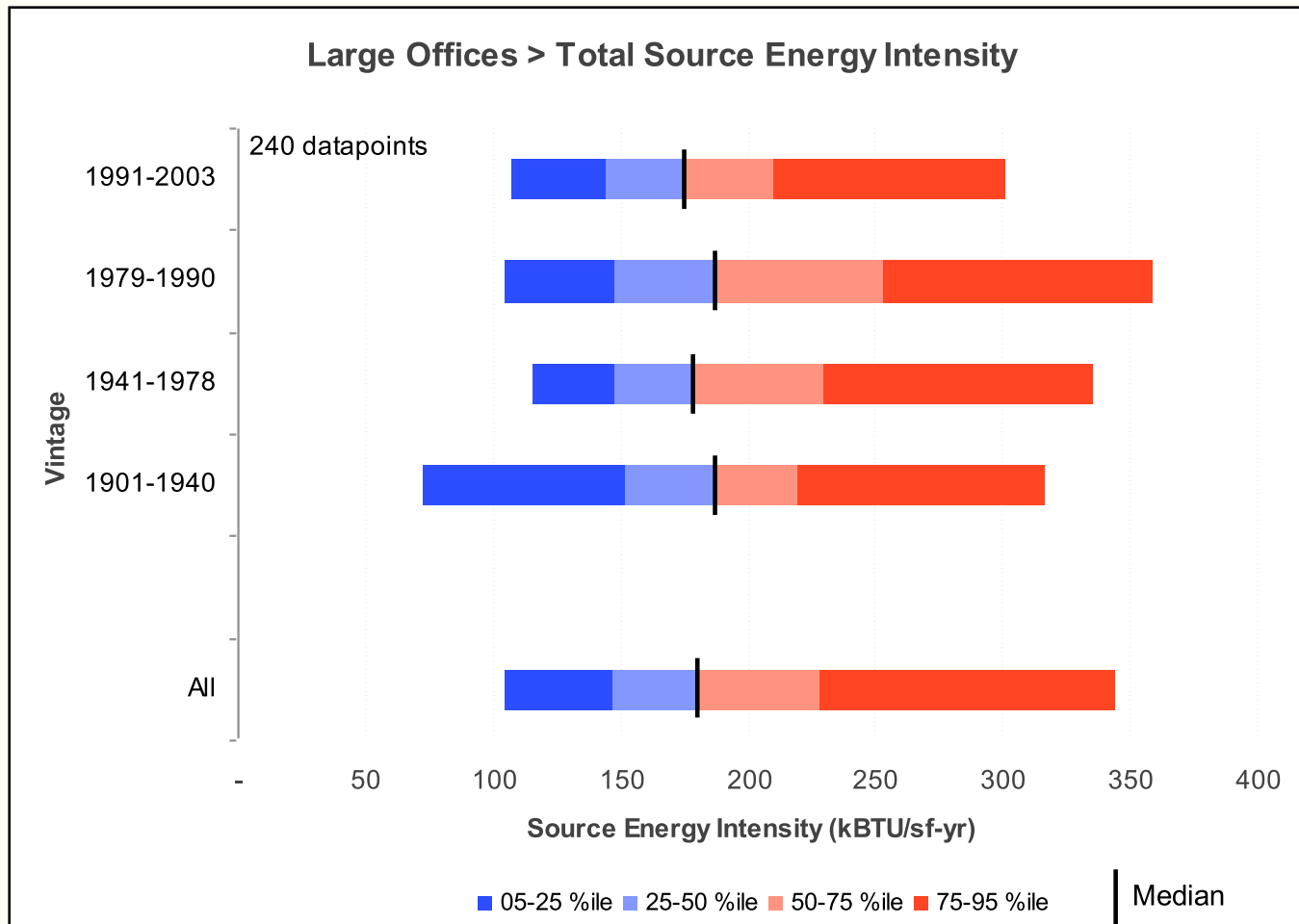


Whole Building Energy Intensity → Overall Efficiency Potential



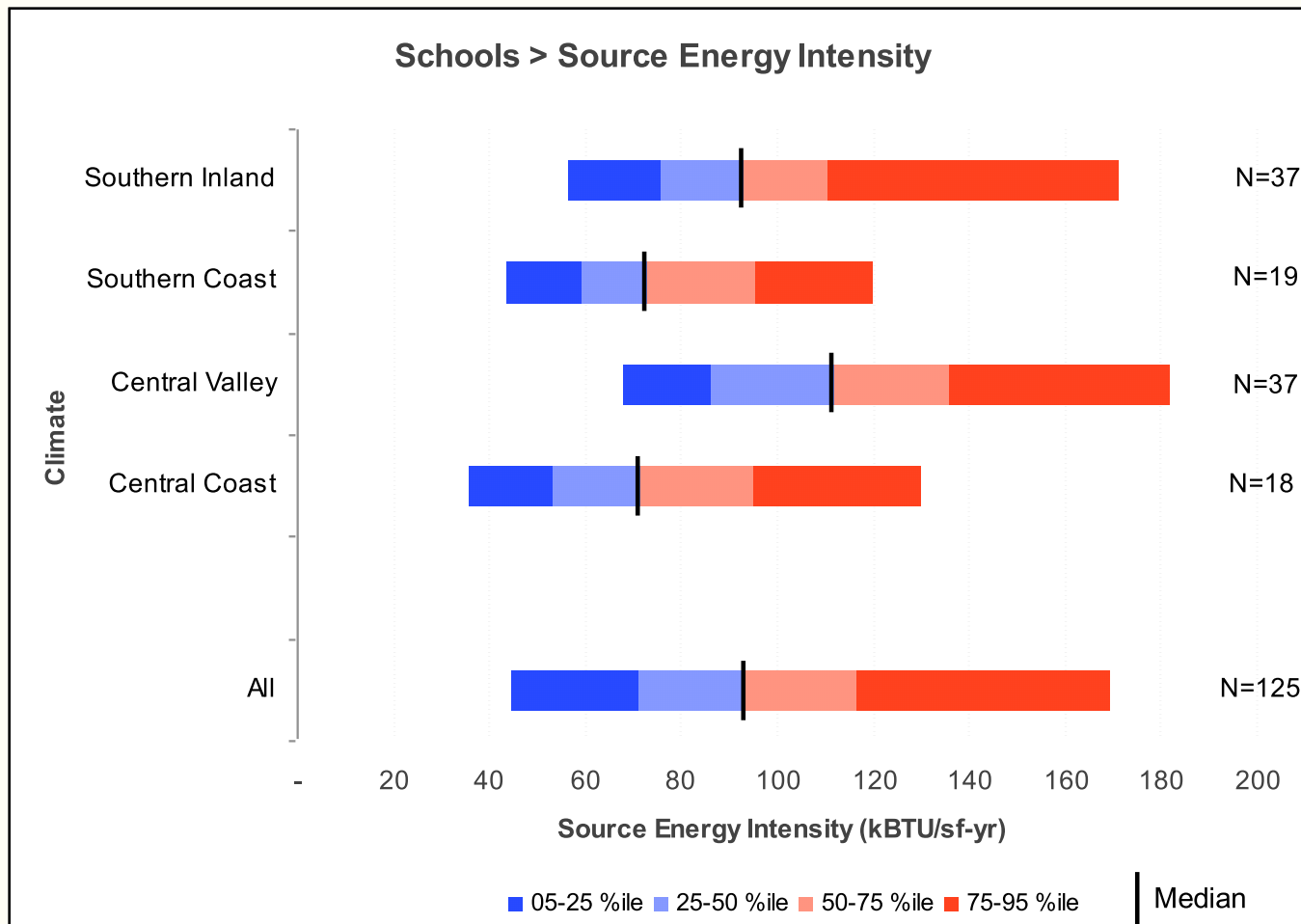
Whole Building Energy Intensity

→ Overall Efficiency Potential by Vintage

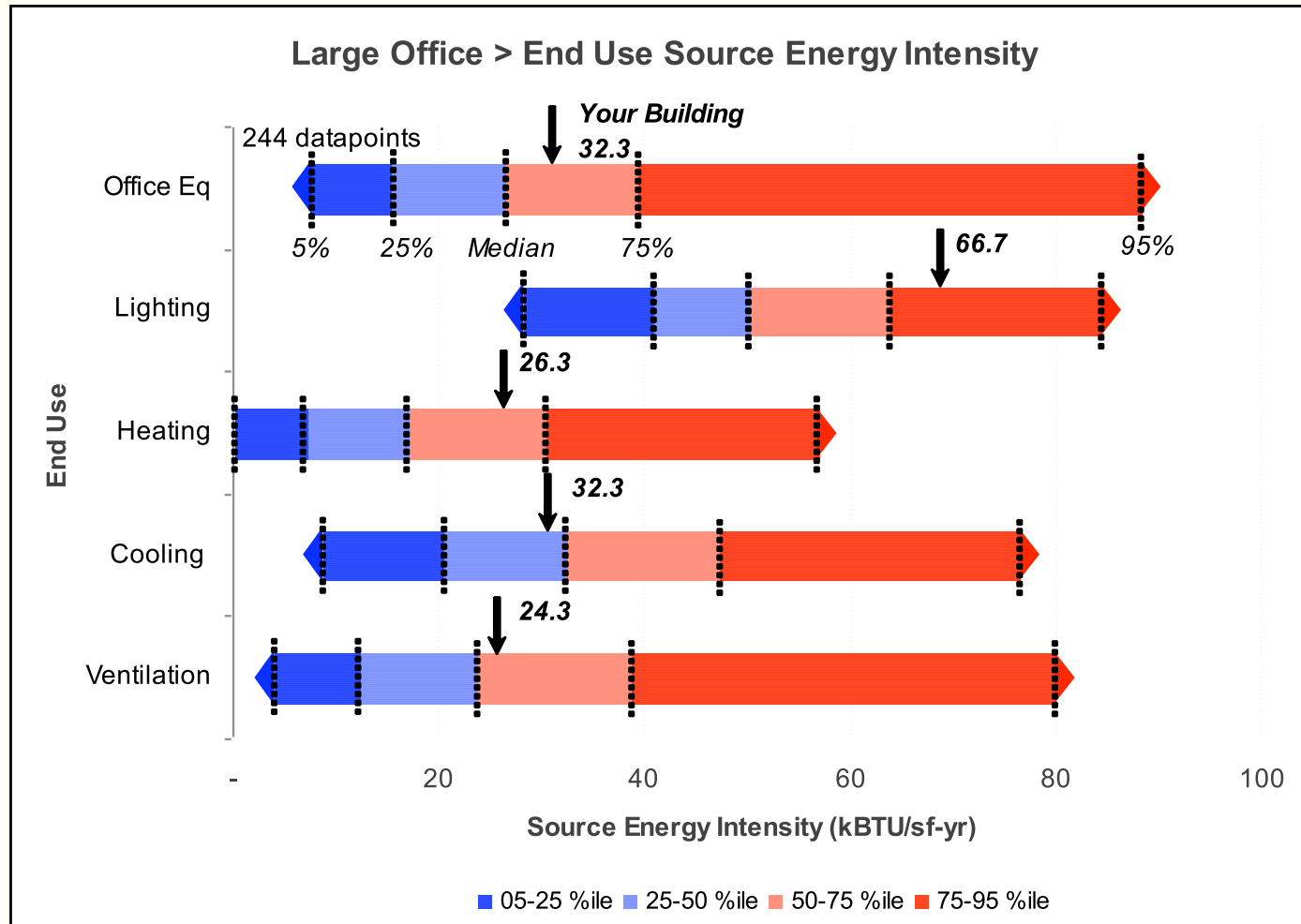


Whole Building Energy Intensity

→ Overall Efficiency Potential by Climate



End-Use Energy Intensity → System Efficiency Potential





Benchmark

Peer Group

Metric/Feature

Units

View

Current Peer group: 23 Buildings ?

Facility Type

Base Dataset

- ☒ California only (CEUS)
- ☒ U.S. National (CBECS)
- ☒ All Users of EnergyIQ

Location

California [\[Map\]](#)

By ZIP

Floor Area

- ☒ 0 - 25,000 sf
- ☒ 25,001 - 150,000 sf
- ☒ Over 150,000 sf

Vintage

- ☒ 1991 through present
- ☒ 1979 through 1990
- ☒ 1941 through 1978

- ☐ Cleanroom
- ☐ College
 - ☐ College or University
 - ☐ Vocational or Trade School

- ☐ Data Center
- ☐ Laboratory
- ☐ Restaurant

- ☐ Fast Food or Self Service
- ☐ Specialty/Novelty Food Service
- ☐ Other Food Service
- ☐ Bar/Tavern/Nightclub/Other
- ☐ Table Service

- ☐ Food Store
 - ☐ Fast Food or Self Service
 - ☐ Supermarkets
 - ☐ Small General Grocery
 - ☐ Convenience Store
 - ☐ Other Food Store
 - ☐ Liquor Store
 - ☐ Specialty/Ethnic Grocery

- ☐ Lodging
 - ☐ Hotel
 - ☐ Other Lodging
 - ☐ Resort
 - ☐ Motel

- ☒ Office
 - ☒ Administration and Management
 - ☒ Financial/Legal
 - ☒ Insurance/Real Estate
 - ☒ Government Services
 - ☒ Software Development
 - ☒ Medical/Dental Office
 - ☒ Assorted/Multi-tenant
 - ☒ Other Office

- ☐ Retail
 - ☐ Fast Food or Self Service
 - ☐ Department / Variety Store
 - ☐ Retail Warehouse/Clubs
 - ☐ Shop in

- ☐ Public Assembly
 - ☐ Library / Museum
 - ☐ Conference/Convention Center
 - ☐ Religious Assembly (mixed use)
 - ☐ Movie Theaters
 - ☐ Health/Fitness Center
 - ☐ Religious (worship only)
 - ☐ Theater / Performing Arts
 - ☐ Community Center
 - ☐ Other Recreation/Public Assembly

- ☐ School
 - ☐ Daycare or Preschool
 - ☐ Elementary School
 - ☐ Middle / Secondary School

- ☐ Warehouse (Refrig)
- ☐ Warehouse (Non-Refrig)
 - ☐ Unconditioned WH, High Bay
 - ☐ Conditioned WH, Low Bay
 - ☐ Unconditioned WH, Low Bay
 - ☐ Conditioned WH, High Bay



Benchmark

Peer Group

Metric/Feature

Units

View

Current Peer group: 23 Buildings ?

Select Units >>

Metrics

- ☐ Total Energy
- ☐ Total Electricity
- ☒ Total Fuel

End Use Breakout

- ☐ Total
- ☐ Electricity
- ☐ Fuel

End Uses

- ☐ Lighting
- ☐ Heating
- ☐ Cooling
- ☐ Ventilation
- ☐ Service Hot Water
- ☐ Office Equip.
- ☐ Refrigeration
- ☐ Cooking
- ☐ Motors

Features

Envelope

- ☐ Roof Insulation
- ☐ Wall Insulation
- ☐ Glazing Type
- ☐ Exterior Shading
- ☐ Interior Shading

Chilled Water

- ☐ Chillers
- ☐ Chilled Water Pumps
- ☐ Heat Rejection

Hot Water / Steam

- ☐ Boiler
- ☐ Pumps
- ☐ Hot Water / Steam
- ☐ Boiler
- ☐ Pumps

Service Hot Water

Lighting

- ☐ Lamp
- ☐ Ballast
- ☐ Control
- ☐ Hours of Use

Plug & Process Loads

- ☐ Office Equip. Intensity
- ☐ Food Service Equip. Intensity
- ☐ Refrigeration Intensity

Single-Zone Air Handlers

- ☐ System type
- ☐ Age
- ☐ Hours
- ☐ Temp Control
- ☐ Optimal start/stop
- ☐ Economizer
- ☐ Outside Air
- ☐ Supply Fan Motor Eff

Multi-Zone Air Handlers

- ☐ System type
- ☐ Age
- ☐ Hours
- ☐ Temp Control
- ☐ Optimal start/stop
- ☐ Economizer type
- ☐ Outside Air
- ☐ Supply Fan Motor Eff
- ☐ Supply Airflow Efficiency
- ☐ Supply fan control (VAV)
- ☐ Return Fan Motor Eff
- ☐ Return Airflow Efficiency
- ☐ Return fan control (VAV)
- ☐ Cooling Type
- ☐ Cooling Efficiency
- ☐ Heating Type
- ☐ Heating Fuel
- ☐ Heating Efficiency
- ☐ Perimeter terminal type
- ☐ Perimeter reheat fuel



Benchmark

Peer Group

Metric/Feature

Units

Views

Cost



\$/sf-yr



\$/sq.m-yr

Source Energy



kBTU/sf-yr



MJ/sq.m-yr



kWh/sq.m-yr

Site Energy



kWh/sf-yr



kBTU/sf-yr



MJ/sq.m-yr



kWh/sq.m-yr

Emissions



lbs. CO2/sf-yr



lbs. CO2e/sf-yr



kg. CO2/sq.m-yr



kg. CO2e/sq.m-yr

<< Select Metric / Feature

Select Views >>



Benchmark

Peer Group

Metric/Feature

Units

Views

Point in time

- ☐ Text summary
- ☐ Range bar chart
- ☐ Ranked bar chart
- ☐ Frequency distributio

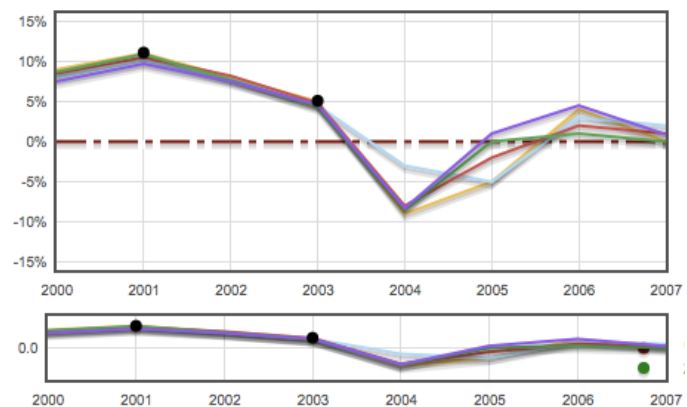
Over time

- ☐ Raw data
- ☐ Deviation from peers
- ☒ Deviation from target

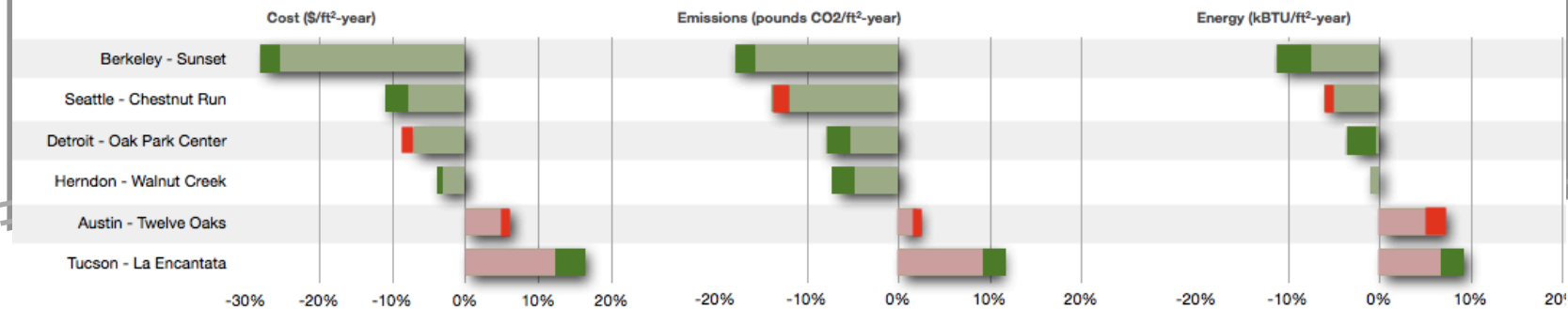
<< Select Metric/Feature

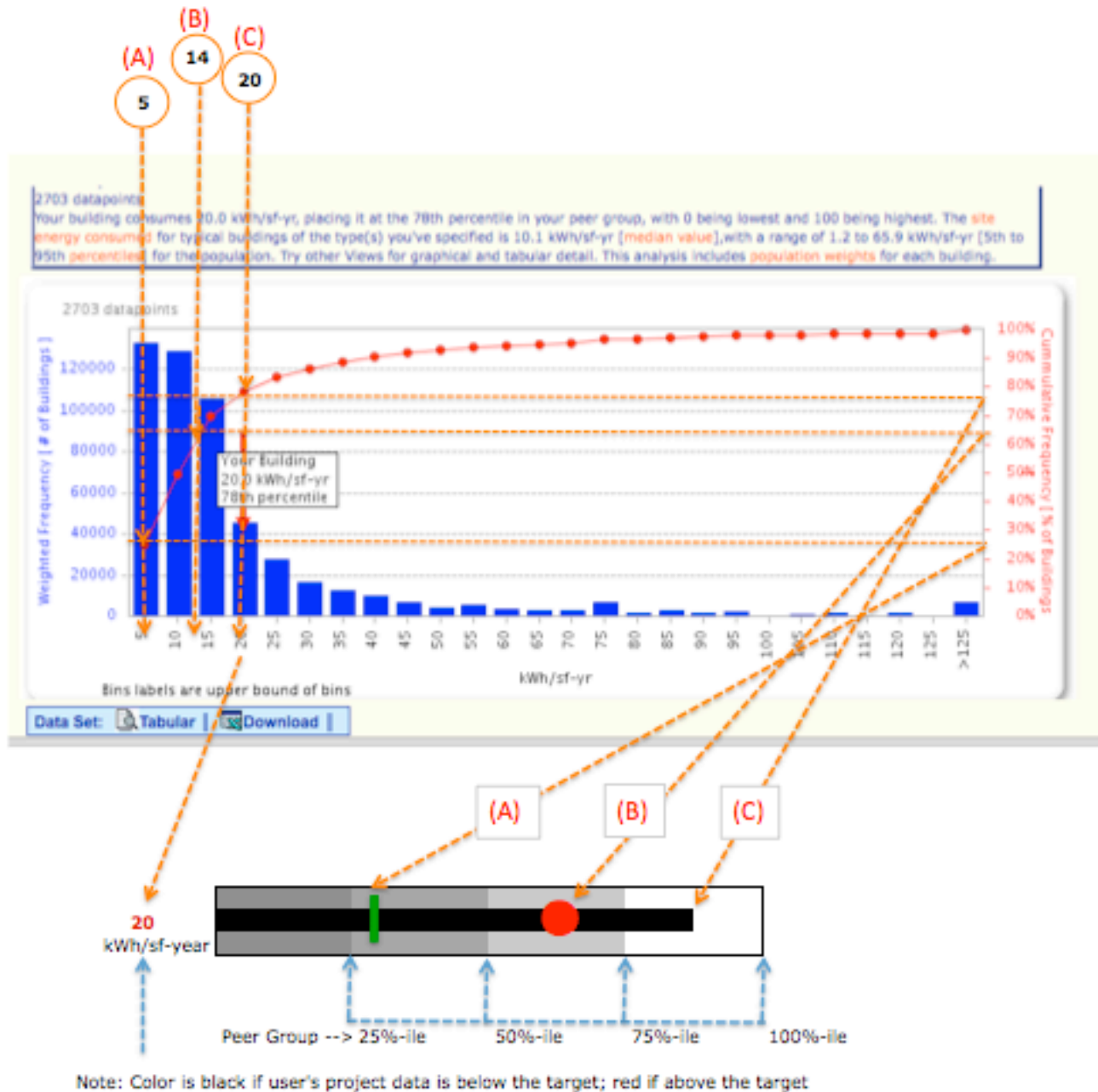
Show Benchmark >>

Ex



End Use	Action	Status	Cost Effectiveness	Comments
Lighting	L-2 Installed occupancy controls	20 July 2009	<input type="radio"/>	
Lighting	L-1 T5 Lamp and ballast retrofit	11 April 2009	<input checked="" type="radio"/>	
Lighting	T-5 Lamp and ballast retrofit	11 April 2009	<input checked="" type="radio"/>	
Air Handling	A-1 Reduce operating hours	Pending	<input type="radio"/>	





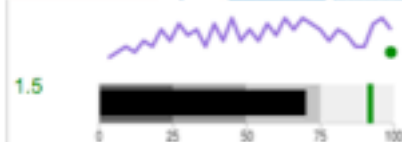


Filters

- ▶ Compare
- ▶ Set Target

Cost (\$/ft²-year)

Top 10 Bottom 10 View All



Fuel

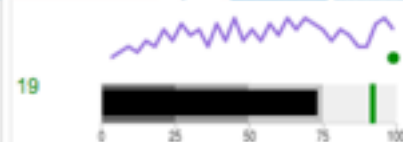


Electricity



Emissions (pounds CO₂/ft²-year)

Top 10 Bottom 10 View All



Fuel

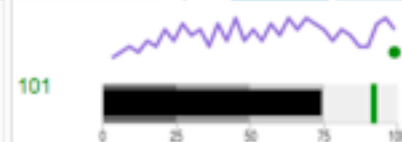


Electricity



Energy (kBtu/ft²-year)

Top 10 Bottom 10 View All



Fuel



Electricity



Actions

Rec'd	Taken	Rej'd
41	67	9

Facilities

Oaks Office Building

Fairview Suites

Downtown Offices

INDIVIDUAL BUILDINGS



Actions

Rec'd	Taken	Rej'd
41	67	9
41	67	9
41	67	9

Related companies Show: Most Recent Annual		Add or remove columns				
		Valuation				
	Company name	Price	Change	Chg %	d m y	Mkt Cap
NFLX	Netflix, Inc.	83.37	+3.38	4.23%		4.46B
BBI	Blockbuster Inc.	0.251	-0.019	-7.04%		52.62M
CSTR	Coinstar, Inc.	34.65	+0.78	2.30%		1.08B
MVGRQ	Movie Gallery, Inc.	0.0400	0.0000	0.00%		1.50M
4756	Culture Convenience Cl...	493.00	+11.00	2.28%		95.09B
QFX	Quickflix Ltd.	0.076	+0.001	1.33%		13.04M
4724	SHICHIE Co., Ltd.	360.00	+3.00	0.84%		3.57B
CECS	CECS Corp.	0.0005	0.0000	0.00%		31,485.00
WCEC	West Coast Entertainment	0.0050	0.0000	0.00%		71,050.00
HAST	Hastings Entertainment...	4.48	+0.02	0.45%		42.65M
Game Trading Technolog...	Game Trading Tech., Inc.			%		

Personal Info

Federal Taxes

Federal Review

Finish Up

Review & Plan

Error Check

Audit Support

Your Audit Risk Summary



We've reviewed your return for some common situations that have historical
[More](#)

Here's what we found:

Your audit risk is medium. Please select **Show Details** to see important information in your
audit risk analysis.

You have a Schedule C as part of your tax return.

☐ Show Details

Thank You!



emills@lbl.gov

<http://evanmills.lbl.gov>

<http://energybenchmarking.lbl.gov>